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2011 MARINE CORPS SYSTEMS COMMAND SMALL BUSINESS OPPORTUNITIES CONFERENCE

December 14, 2011

Fredericksburg, VA

Agenda

Wednesday, December 14, 2011

MCSC COMMANDER KEYNOTE ADDRESS

- BGen Frank L. Kelley, USMC, *Commander, Marine Corps Systems Command*

DOING BUSINESS WITH MCSC AND PEOs

Panelists:

- Ms. Karen Davis, *Product Group Director, Information Systems and Infrastructure (ISI) (PG 10)*
- Mr. Andrew Dwyer, *Program Manager, Global Combat Support System-Marine Corps (GCSS-MC (PEO EIS))*
- Mr. Paul Ortiz, *Director, Acquisition Center for Sport Services (ACSS); CEOss Business Model*
- Col Peter Reddy, USMC, *Product Group Director, MAGTF C2, Weapons & Sensors Development & Integration (MC2I) (PG 11)*
- Col Joseph Shrader, USMC, *Product Group Director, Combat Equipment and Support Systems (CESS) (PG16) Product Group Director, Armor and Fire Support Systems (AFSS) (PG14)*
- LtCol David Thompson, USMC, *Program Manager, Robotic Systems Joint Project Office*
 - UGVs in the Fight - Making a Difference
 - Unmanned Ground Systems Roadmap
 - Unmanned Systems Integrated Roadmap FY2011-2036
- Mr. Jack Cave, *Product Group Director, Ground Transportation and Engineer Systems (GTES) (PG15)*

DEPARTMENT OF NAVY MENTOR PROTÉGÉ PRESENTATION - A CONTINUING SUCCESS STORY NORTHROP GRUMMAN AND CUSTOM MANUFACTURING AND ENGINEERING (CME)

- Dr. Nancy Crews, *President, CME*
- Ms. Oreta Stinson, *Deputy Director, Navy Office of Small Business Program*

MCSC SENIOR EXECUTIVE KEYNOTE ADDRESS

Senior Executive Service:

- Mr. James H. Smerchansky, *Deputy Commander, SIAT*

MARINE CORPS SYSTEMS COMMAND

SMALL BUSINESS OPPORTUNITIES CONFERENCE



CONFERENCE AGENDA

FREDERICKSBURG EXPO CENTER ► FREDERICKSBURG, VA

DECEMBER 14, 2011

WWW.NDIA.ORG/MEETINGS/2970

EVENT #2970

WEDNESDAY DECEMBER 14 2011

6:00 am - 7:00 am

TABLE TOP EXHIBITOR REGISTRATION — BALLROOM FOYER

6:00 am - 7:00 am

TABLE TOP EXHIBIT SET UP — EXHIBIT HALL A

7:00 am - 5:00 pm

ATTENDEE REGISTRATION — BALLROOM FOYER

7:00 am - 8:00 am

CONTINENTAL BREAKFAST— EXHIBIT HALL A

8:00 am - 8:05 am

WELCOME, PLEDGE AND INTRODUCTORY REMARKS — BALLROOM BCDE

- ▶ Mr. David Dawson, *Associate Director for Small Business Programs, Marine Corps Systems Command*

8:05 am - 8:25 am

WELCOME TO CONFERENCE

- ▶ Congressman Rob Wittman (VA-1), *U.S. Congress*

8:25 am - 8:55 am

MCSC COMMANDER KEYNOTE ADDRESS

- ▶ BGen Frank L. Kelley, USMC, *Commander, Marine Corps Systems Command*

8:55 am - 9:20 am

MCSC EXECUTIVE DIRECTOR KEYNOTE ADDRESS

- ▶ Dr. John D. Burrows, *Executive Director, Marine Corps Systems Command*

9:20 am - 9:45 am

DEPARTMENT OF NAVY OFFICE OF SMALL BUSINESS PROGRAMS (DON OSBP) DIRECTOR
KEYNOTE ADDRESS

- ▶ RADM Seán F. Crean, SC, USN, *Director, DON OSBP* (Confirmed)

9:45 am - 10:00 am

NETWORKING/REFRESHMENTS BREAK — EXHIBIT HALL A

WEDNESDAY DECEMBER 14 2011

10:00 am - 12:45 pm

EXHIBIT HALL OPEN TO VIEW EXHIBIT ONLY (VEO) PASS HOLDERS — EXHIBIT HALL A

10:00 am - 12:45 pm

CONCURRENT BREAKOUT SESSIONS — BALLROOM BCDE & F

SESSION I — BALLROOM BCDE

10:00 am - 11:20 am

DOING BUSINESS WITH MCSC AND PEOs

Moderator:

- ▶ Mr. David Dawson, *Associate Director for Small Business Programs, Marine Corps Systems Command*

Panelists:

- ▶ Ms. Karen Davis, *Product Group Director, Information Systems and Infrastructure (ISI) (PG 10)*
- ▶ Mr. Andrew Dwyer, *Program Manager, Global Combat Support System-Marine Corps (GCSS-MC (PEO EIS))*
- ▶ Mr. Paul Ortiz, *Director, Acquisition Center for Support Services (ACSS); CEO's Business Model*
- ▶ Col Peter Reddy, USMC, *Product Group Director, MAGTF C2, Weapons & Sensors Development & Integration (MC2I) (PG 11)*
- ▶ Mr. James Solomon, *Assistant Product Group Director for Program Management, Communications, Intelligence, & Networking Systems (CINS) (PG12)*

SESSION II — BALLROOM F

10:00 am - 11:20 am

DOING BUSINESS WITH MCSC AND PEOs

Moderator:

- ▶ Mr. Austin (AJ) Johnson, *Small Business Deputy, Marine Corps Systems Command*

Panelists:

- ▶ Col Andrew Bianca, USMC, *Product Group Director, Infantry Weapons Systems (IWS) (PG13)*
- ▶ Col Joseph Shrader, USMC, *Product Group Director, Combat Equipment and Support Systems (CESS) (PG16)*
Product Group Director, Armor and Fire Support Systems (AFSS) (PG14)
- ▶ Col David Smith, USMC, *Program Manager, Training Systems (PM TRASYs)*
- ▶ LtCol David Thompson, USMC, *Program Manager, Robotic Systems Joint Project Office*

WEDNESDAY DECEMBER 14 2011

SESSION III — BALLROOM BCDE

11:25 am - 12:45 pm

DOING BUSINESS WITH MCSC AND PEOs

Moderator:

- ▶ Mr. David Dawson, *Associate Director for Small Business Programs, Marine Corps Systems Command*

Panelists:

- ▶ Col Brian Buckles, USMC, *Program Manager, Light Armored Vehicles (LAV)*
- ▶ Mr. Jack Cave, *Product Group Director, Ground Transportation and Engineer Systems (GTES) (PG15)*
- ▶ Mr. David Hansen, *Joint Program Manager, Mine Resistant Ambush Protected (MRAP) Vehicle Program*
- ▶ Mr. David Karcher, *Director, Energy & Counter-Improvised Explosive Devices (C-IED)*

SESSION IV — BALLROOM F

11:25 am - 12:45 pm

**DEPARTMENT OF NAVY MENTOR PROTÉGÉ PRESENTATION -
A CONTINUING SUCCESS STORY NORTHRUP GRUMMAN AND CUSTOM
MANUFACTURING AND ENGINEERING (CME)**

Moderator:

- ▶ Mr. Austin (AJ) Johnson, *Small Business Deputy, Marine Corps Systems Command*

Panelists:

- ▶ Mr. John R. Brown, *Project Manager, Mentor Protégé Program, Northrup Grumman*
- ▶ Dr. Nancy Crews, *President, CME*
- ▶ Ms. Oreta Stinson, *Deputy Director, Navy Office of Small Business Program*

12:50 pm - 1:40 pm

LUNCH — EXHIBIT HALL A

12:50 pm - 1:40 pm

EXHIBIT HALL CLOSED DURING LUNCH

1:40 pm - 4:30 pm

EXHIBIT HALL RE-OPENS FOR ATTENDEES

WEDNESDAY **DECEMBER 14** 2011

1:40 pm - 2:05 pm

MCSC SENIOR EXECUTIVE KEYNOTE ADDRESS — BALLROOM BCDE

Moderator:

- ▶ Mr. David Dawson, *Associate Director for Small Business Programs, Marine Corps Systems Command*

Senior Executive Service:

- ▶ Mr. James H. Smerchansky, *Deputy Commander, SIAT*

2:05 pm - 6:00 pm

BUSINESS MATCHMAKING SESSIONS — BALLROOM AF

15 minute appointments with Department of Navy and Marine Corps Systems Command Product Group and PM Representatives — By appointment only

3:15 pm - 4:00 pm

NETWORKING/REFRESHMENTS BREAK — EXHIBIT HALL A

4:30 pm - 6:00 pm

TABLE TOP EXHIBITOR TEAR DOWN

6:00 pm

CONFERENCE ADJOURNS

EXHIBITS BY ORGANIZATION

ORGANIZATION	BOOTH
ACCENT CONTROLS, INC.	69
ACCUSONIC VOICE SYSTEMS	96
ACII, INC.	91
ACUMENTRICS CORPORATION	57
ADVANCED CONCEPTS AND TECHNOLOGIES INTERNATIONAL, LLC	17
AMERICAN INNOVATIONS, INC.	82
ARNCO, INC.	47
ATTACK PAK	101
AVIAN ENGINEERING LLC	81
BCDS INC.	9
BIOQUELL DEFENSE, INC	39
BOB HUNT	22
CASK TECHNOLOGIES, LLC	2
CATALYST SOLUTIONS, LLC	23
CBAI & ASSOCIATES	73
CHENEGA GLOBAL SERVICES, LLC	79
CHUGACH ALASKA CORPORATION	58
COGENT SOLUTIONS	40
CONSCIOUS SECURITY	92
CORNERSTONE INTEGRATION, INC.	27
CORNET TECHNOLOGY, INC.	48
CSSS.NET	70
CUSTOM MANUFACTURING & ENGINEERING, INC.	21
DATA MATRIX SOLUTIONS, INC.	66
DATA SYSTEMS & TECHNOLOGY, INC.	72
DAVIS-PAIGE MANAGEMENT SYSTEMS, LLC	59
DESIGN MILL, INC.	36
DISTRIBUTED INFORMATION TECHNOLOGIES, INC.	83
DOD CONTRACTORS.ORG, LLC	84
DULLES CASE CENTER, LLC	8
FALCON INDUSTRIES, INC.	28
FLATTER & ASSOCIATES, INC.	29
FNNTEK, INC.	41
G55, LLC.	78
GLOBAL INFOTEK, INC.	16
GLOBAL SUPPLY SOLUTIONS, LLC	4
GTI FEDERAL, INC.	85
HINCKLEY	93
IAN HICKS	102
IDS INTERNATIONAL	51
IMMEDIATE RESPONSE TECHNOLOGIES, INC.	18
IMSOLUTIONS, LLC	60
INFORMATION SCIENCES CONSULTING, INC.	97
INNOVATIVE DEFENSE TECHNOLOGIES	3
INNOVATIVE REASONING, LLC	61
JRC INTEGRATED SYSTEMS, INC.	94
KEYSTONE FIRE PROTECTION CO.	11
KNOWLEDGE CONNECTIONS, INC.	100
KRISTIN MCINERNEY	6
LAW ENFORCEMENT ASSOCIATES, INC.	10
LIND ELECTRONICS, INC.	53
LOGIS-TECH, INC.	71
MAINSTREAM ENGINEERING CORPORATION	80
MANAGEMENT SCIENCES, INC.	32
MANTARO PRODUCT DEVELOPMENT SERVICES	7

ORGANIZATION	BOOTH
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METROSTAR SYSTEMS, INC.	52
MLT SYSTEMS	49
NATIONAL ASSOCIATION OF FEDERAL CONTRACTORS	54
NATIONAL INDUSTRIES FOR THE BLIND	103
NEOHARBOR INTERNATIONAL, LLC.	42
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NOVA POWER SOLUTIONS, INC.	24
OCTO CONSULTING GROUP	87
PAC SOLUTIONS LLC	74
PARAMOUNT INDUSTRIES INC.	50
PARROCO PRODUCTIONS	88
POLAR THERM OY	95
PROFESSIONAL SOLUTIONS DELIVERED	43
QSACK & ASSOCIATES, INC.	34
QUADELTA, INC.	62
QUANTUM RESEARCH INTERNATIONAL	89
RABABY & ASSOCIATES	19
RCT SYSTEMS INC.	63
RNB TECHNOLOGIES, INC.	56
S&K TECHNOLOGIES, INC.	12
SAAB BARRACUDA LLC	201
SECHAN ELECTRONICS, INC.	90
SHARON CONTI	37
SILVER BULLET SOLUTIONS, INC.	75
SIMVENTIONS	64
SOLIDICA, INC.	46
SPOT TERRF	14
STRATOM, INC.	15
STRIKE GROUP LLC	55
STUDIO 14B	20
SYNEXXUS, INC.	76
SYNTONICS, LLC	30
T&W OPERATIONS, INC.	13
TACTICAL MICRO	25
TATITLAK CORPORATION	1
TECMOTIV (U.S.A.), INC.	44
THE CENTECH GROUP, INC.	200
THE PROMETHEUS COMPANY	65
THOMAS ASSOCIATES INC.	35
THOR POWER CORPORATION	31
TKH SECURITY-USA	5
TRX SYSTEMS, INC.	68
UEC ELECTRONICS, LLC	77
UNANET TECHNOLOGIES	104
VAN CLEVE AND ASSOCIATES	38
WEB BUSINESS SOLUTIONS, INC.	98
WESTWIND TECHNOLOGIES, INC.	45
WOLF CREEK FABRICATION SERVICES, INC.	26
WORKING WARRIORS, A POWERBAND COMPANY	99
ZOOM INC.	105

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BOOTH	ORGANIZATION
1	TATITLEK CORPORATION
2	CASK TECHNOLOGIES, LLC
3	INNOVATIVE DEFENSE TECHNOLOGIES
4	GLOBAL SUPPLY SOLUTIONS, LLC
5	TKH SECURITY-USA
6	KRISTIN MCINERNEY
7	MANTARO PRODUCT DEVELOPMENT SERVICES
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51	IDS INTERNATIONAL
52	METROSTAR SYSTEMS, INC.
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55	STRIKE GROUP LLC

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101	ATTACK PAK
102	IAN HICKS
103	NATIONAL INDUSTRIES FOR THE BLIND
104	UNANET TECHNOLOGIES
105	ZOOM INC
200	THE CENTECH GROUP, INC.
201	SAAB BARRACUDA LLC

TABLE TOP EXHIBITS FLOOR PLAN

TO LUNCH



102
101

100
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73
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200



201

TO REGISTRATION/CONFERENCE SESSIONS



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Systems and Software**

THANK YOU TO OUR AGENDA AD SPONSORS



THANK YOU TO OUR LARGE COMPANY TABLE TOP SPONSORS



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L-3 Command & Control Systems and Software (C2S2) provides systems and software engineering and integration, software development, sustainment and modernization, training, field support services, and logistics capabilities for military and federal use.

The Expeditionary Acquisition & Logistics department of C2S2, based in Dumfries, VA, provides innovative, realistic, warfighter training, CBRN support, acquisition and logistics expertise, and intelligence support.

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- Integration of Marine Corps and Joint combat lessons learned
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- Project management experts across all training venues

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- Acquisition and logistics experts
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- Active within multiple Joint programs
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JOIN THE L-3 TEAM**

For more information on how we partner with small businesses, please contact Donna Payton at 703.445.0840 or via email at donna.payton@L-3com.com.



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**BETWEEN A VISION AND AN OUTCOME,
THERE IS ONE IMPORTANT WORD: HOW.**

We take our commitment to the community seriously. Without support for small businesses, communities would not be able to develop economically. Helping small businesses thrive is all a question of How. And it is the How that makes all the difference

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IECU

Improved Environmental Control Units



9K/115VAC	NSN 4120015927940
18K/230VAC	NSN 4120015927977
18K/208VAC	NSN 4120015927987
36K/208VAC	NSN 4120015927949

TRCS/QRCS

Tricon or Quadcon Refrigerated Container Systems



TRCS Type I	NSN 8145-01-598-4828
TRCS Type III	NSN 8145-01-598-4829
QRCS	W911QY-07-D-0031

7K/115VAC	MRU-TQ1-404
9K/208VAC	MRU-TQ3-404



Visit Our Booth at the Show
or www.mainstream-engr.com

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NOTES

MCSC SMALL BUSINESS
OPPORTUNITIES CONFERENCE

NOTES

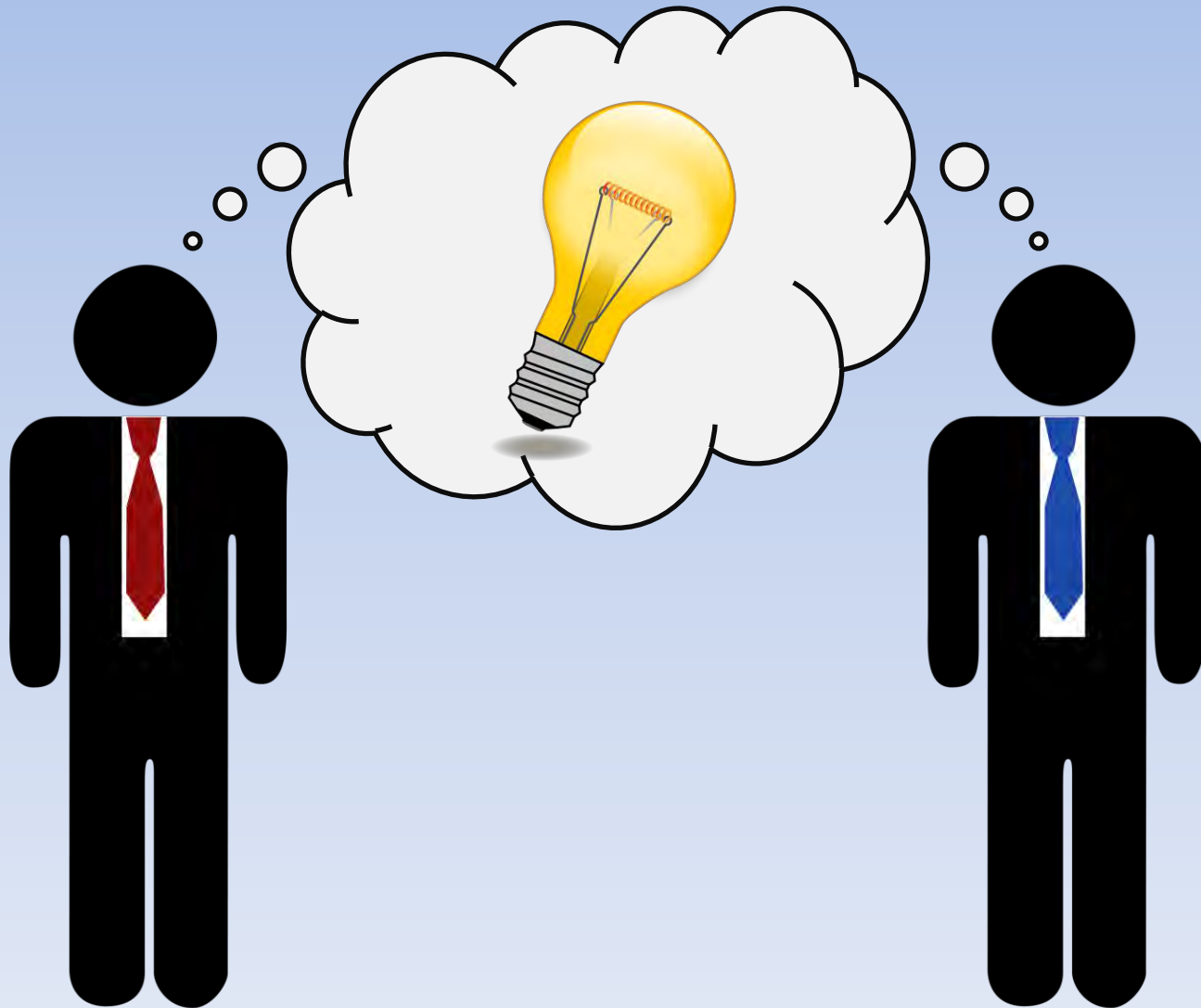
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PROCEEDINGS WILL BE AVAILABLE FOR DOWNLOAD WITHIN 2 WEEKS OF THE CONFERENCE AT:

<http://www.dtic.mil/ndia/2011MCSC/2011MCSC.html>



Meet the Small Business owners of General K & Doctor J Technologies



Small Business Engagement Model for General K & Doctor J Technologies

Perform
Market
Research



Perform Market Research



Study and know the government agency to which you are marketing your products and services.

Understand what products and services that the government agency procures on an annual basis by performing market research using the following tools:

- Federal Procurement Data System – Next Generation (FPDS-NG) https://www.fpds.gov/fpdsng_cms/
- Federal Funding Accountability and Transparency Act (FFATA) <http://www.ffata.org/ffata/>
- Navy Electronic Commerce On-Line (NECO) <https://www.neco.navy.mil/>
- Federal Business Opportunities (FEDBIZOPPS) <https://www.fbo.gov/>



CMC Priorities

CMC PRIORITY

1) Continue to provide the best trained and equipped Marine units to Afghanistan. This will not change. This remains our top priority!

2) Rebalance our Corps, posture it for the future and aggressively experiment with and implement new capabilities and organizations.

3) Better educate and train our Marines to succeed in distributed operations and increasingly complex environments.

4) Keep faith with our Marines, our Sailors and our families.





ASN RDA Priorities

ASN RDA Priorities

- 1) Getting the requirements right
- 2) Making every dollar count
- 3) Performing to plan
- 4) Minding the health of the industrial base
- 5) Strengthening the acquisition workforce





SECNAV

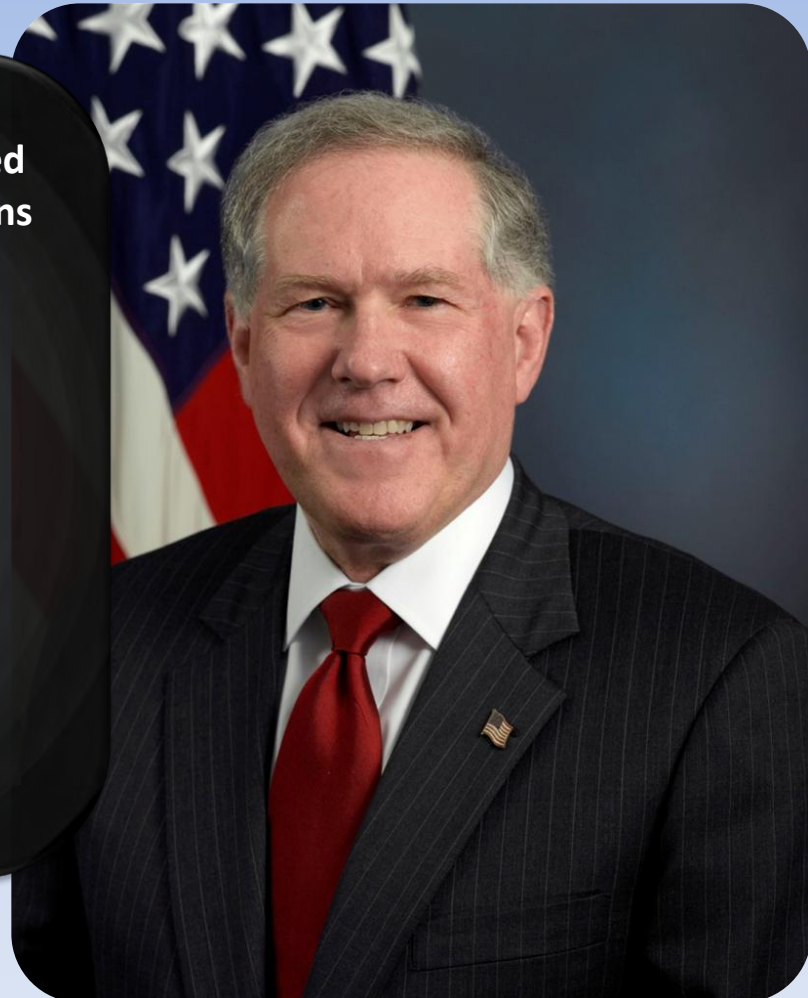
- 1) Taking care of Sailors, Marines, Civilians and their families**
- 2) Treating Navy energy requirements and solutions as issues of national security**
- 3) Creating acquisition excellence**
- 4) Optimizing unmanned systems**





AT&L Priorities

- 1) Supporting forces who are engaged in overseas Contingency Operations
- 2) Achieving affordable programs
- 3) Improving efficiency
- 4) Strengthening the industrial base
- 5) Strengthening our acquisition workforce
- 6) We must protect the future



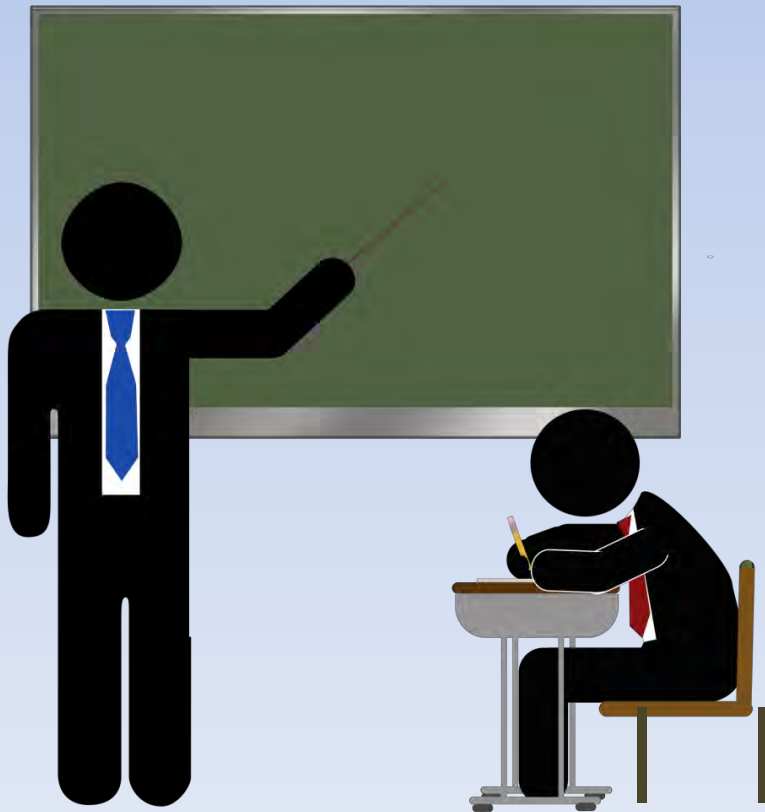
Small Business Engagement Model for General K & Doctor J Technologies

Perform
Market
Research



Invest In &
Educate
Yourself

Invest In & Educate Yourself



Attain professional certifications; training (i.e., acquisition training) through Defense Acquisition University (DAU), ESI International, Management Concepts.

Attend Business Matchmaking events and meet with both government and large business representatives (Business Matchmaking (BMM)).

<http://www.businessmatchmaking.com/>

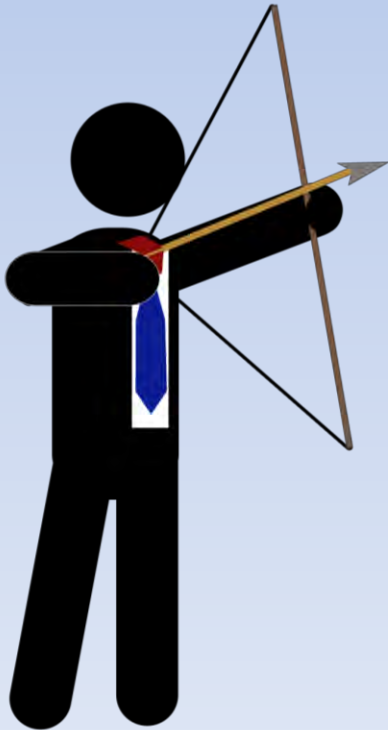
Attend Small Business Training Conferences.

Read available Marine Corps publications & news and Naval proceedings.

Small Business Engagement Model for General K & Doctor J Technologies



Tighten your Aim



Focus on your capabilities and technical solutions to MCSC requirements; not your small business status.

Find a unique skill or ability so that you can meet and market that back to the government agency.

Develop a winning marketing strategy that demonstrates that your small business has the capability to meet MCSC requirements.

Develop innovative technical solutions specific to MCSC requirements. (i.e, Lightening the Load).

Small Business Engagement Model for General K & Doctor J Technologies

Perform
Market
Research



Invest In &
Educate
Yourself



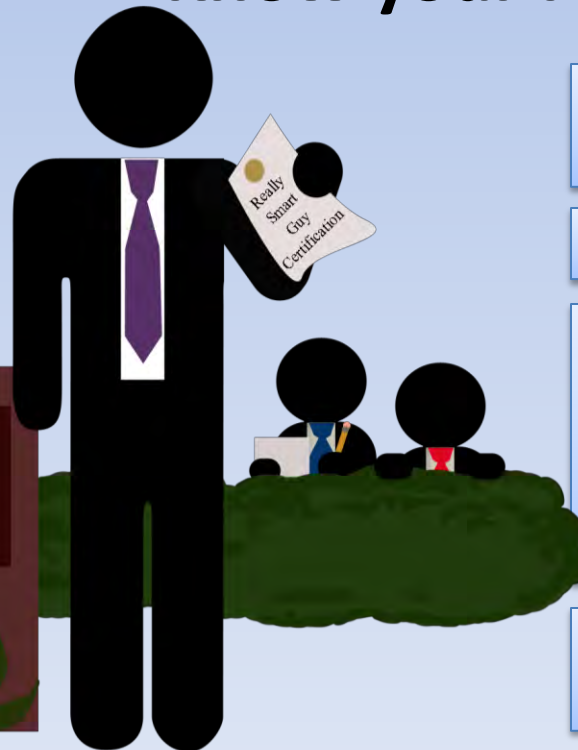
Tighten
your Aim



Know your
Peers



Know your Peers



Know your competition (both large and small).

Consider teaming relationships.

Find out the types of certifications that your competitors have and do whatever is necessary to obtain them (i.e., CMMI Level III; ISO 9000, Lean Six Sigma, etc.).

Establish mentor-protégé relationship with another large or small business.

Small Business Engagement Model for General K & Doctor J Technologies



Stay Informed

Register with FEDBIZOPPS & NECO for all NAICS Codes that are applicable to your company.

<https://www.fbo.gov/> <https://www.neco.navy.mil>

Work with your local Procurement Technical Assistance Program (PTAP), Procurement Technical Assistance Centers (PTAC) Representatives (The PTAP/PTAC Program is a program sponsored by the Defense Logistics Agency)

[.http://www.dla.mil/db/procurem.htm](http://www.dla.mil/db/procurem.htm)

Work with your local Small Business Administration (SBA) <http://www.sba.gov/> & Procurement Center Representative (PCR)

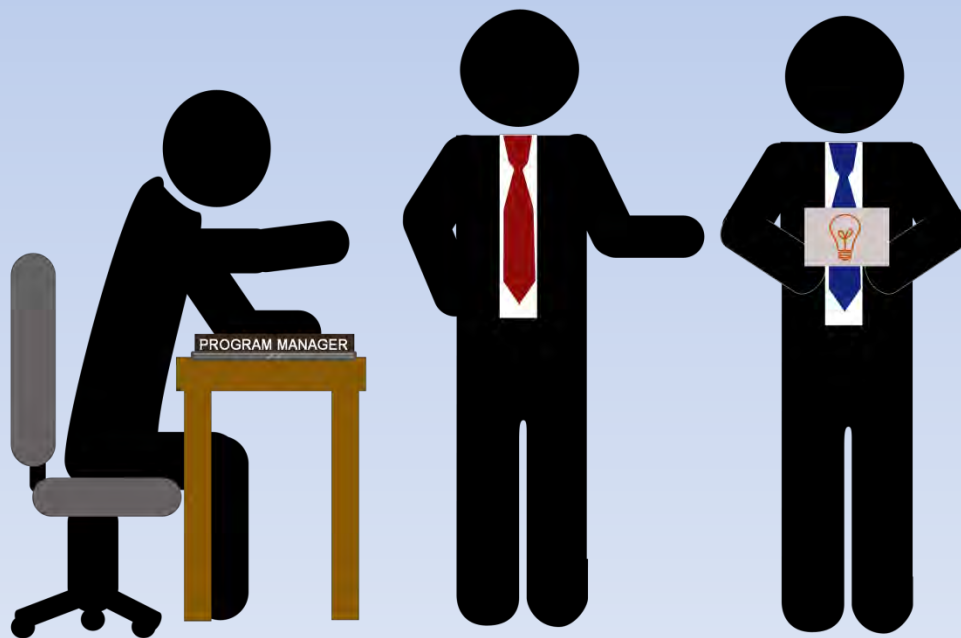
[.http://www.worldlawdirect.com/article/3028/procurement-center-representative-directory.html](http://www.worldlawdirect.com/article/3028/procurement-center-representative-directory.html),



Small Business Engagement Model for General K & Doctor J Technologies



Initiate Positive Engagement and React



Engage at the lowest level to achieve technical and programmable validation (i.e. work with warfare centers and PM's).

Respond to all inquiries in a timely manner.

Respond to Sources Sought and Request for Information (RFI) announcements.

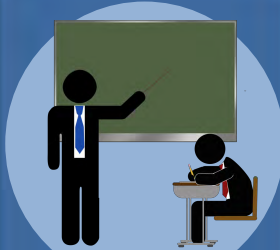
Engage your Small Business Specialists (SBS) as your allies; not your adversaries.

Request Post Award Conferences, Ask for a debriefing whether you are selected for a contract or not (FAR 15.506).

Small Business Engagement Model



Perform
Market
Research



Invest In
&
Educate
Yourself



Tighten
Your Aim



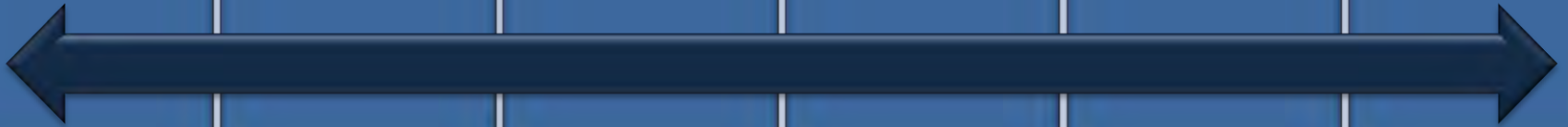
Know
Your
Peers



Stay
Informed



Engage &
React





Ground Transportation and Engineer Systems (GTES) PG-15

Portfolio Overview & Small Business Opportunities

14 Dec 11

MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Program Manager
Expeditionary Power Systems



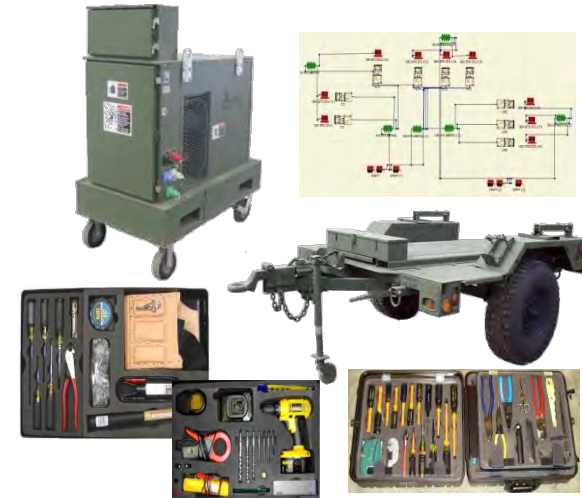
DOD Standard Generators



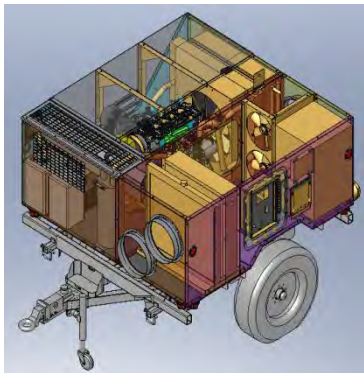
USMC Unique Generators



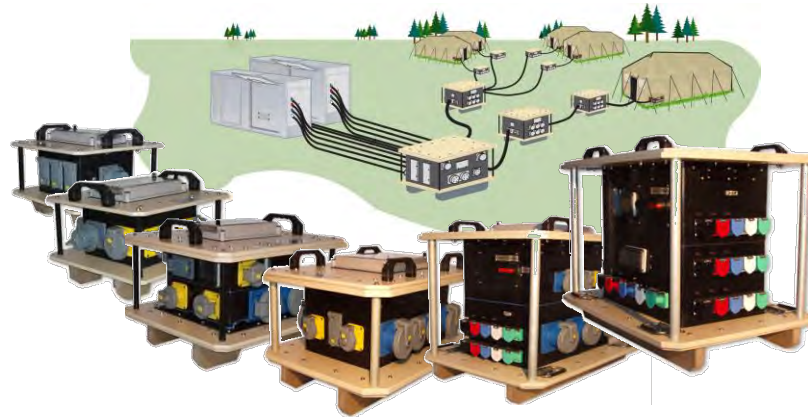
Tools / Customer Support



Integrated Trailer ECU - Generator



Power Distribution



Floodlight Sets





Environmental Control Units



Special Customer ECUs



Field Refrigeration



In-Field Ice Making / Water Chilling (food service, mortuary affairs)



Tools / Customer Support





Power Supplies



Battery Management / Sustainment Systems



MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Program Manager
Expeditionary Power Systems



PALCON



**JOINT MODULAR INTERMODAL
CONTAINER (JMIC)**



QUADCON



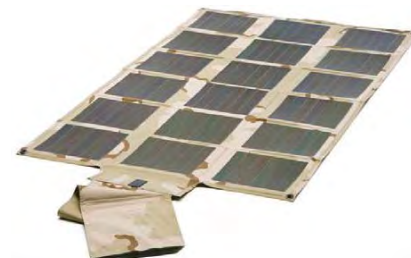
**SMALL FIELD REFRIGERATION SYSTEM
TRICON**



**LARGE FIELD REFRIGERATION SYSTEM
20' ISO**



- Improved AN/PRC-117 Radio Power Adaptor
 - RFP in 3rd QTR FY-12
- Man Portable Renewable Energy System
 - RFP in 3rd QTR FY-12
- Generator / Trailer Interface Kit manufacturing
 - RFP in 4th QTR FY-12
- Environmental Control Unit Acoustic Testing
 - Request for Quote in 2nd QTR FY-12
- Pulse Solar Chargers for Tactical Generators
 - GSA or Small business Request for Quote in 4th QTR FY-12
- Joint Modular Intermodal Container
 - Potential RFP in 1st QTR FY-13





Mine Roller



Vehicle Mounted Mine Detector



Route Clearance Blade



Hand Held Detectors

ENFIRE



Interrogation Arm



MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Program Manager
Engineer Systems



Assault Breacher Vehicle



Mk 154, Mk 155



Armored Combat Earthmover



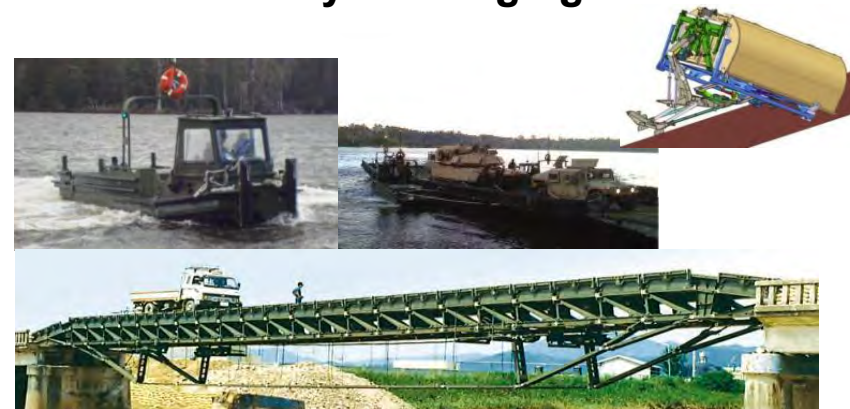
**Family of Explosive
Ordnance Disposal**



Spider



Family of Bridging



MARINE CORPS SYSTEMS COMMAND

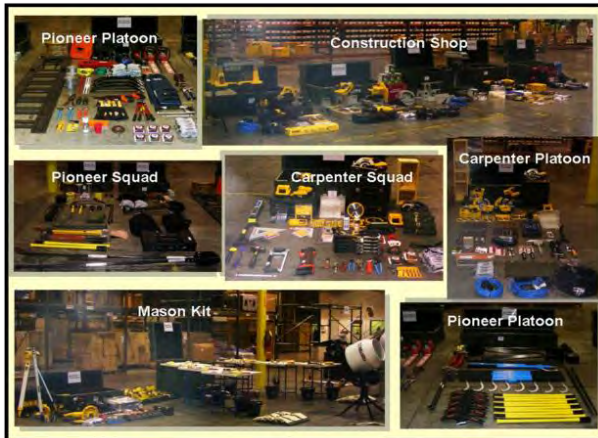
EQUIPPING THE WARFIGHTER TO WIN

Program Manager
Engineer Systems





Family of Engineer and Construction Tool Kits (FECTK)



Water Supply Support Equipment (WSSE)



Tactical Fuel Systems (TFS)





- EOD Technicians Kit
 - RFP in 3rd QTR FY-12



- EOD General Purpose Kit
 - RFP in 3rd QTR FY-12



- EOD IED Kit
 - RFP in 3rd QTR FY-12



- EOD Disposal Kit
 - RFP in 3rd QTR FY-12





- EOD Search Kit
 - RFP in 3rd QTR FY-12



- EOD Disassembly Kit
 - RFP in 3rd QTR FY-12



- 600 Gallons Per Minute (GPM) Fuel and Water pump
 - RFP in 2nd QTR FY-12



- Pipefitters tool kit
 - GSA Quote in 2nd QTR FY-12





PG-15 is looking for opportunities with businesses who exhibit:

- **Innovation**

- Lighter materials and systems
- More energy efficient
- Paradigm in processes and/or products

- **Affordability**

- Cost
- Quality

- **Business Acumen with government agencies**



Lessons Learned: A Protege's Perspective

Dr. Nancy Crews

December 2011

Custom Manufacturing & Engineering, Inc.

3690 70th Avenue North

Pinellas Park, FL 33781-4603

(727) 547-9799

(727) 541-8822 Fax

www.custom-mfg-eng.com



Specifics on Agreement

2

- Mentor-Protégé Agreement
 - U.S. Navy Office of Small Business Programs
- Mentor
 - Northrop Grumman Electronic Systems, Linthicum, MD
 - Program Manager: John Brown
- Sponsor
 - Ground/Air Task Oriented Radar (G/ATOR) Program, U.S. Marine Corps, PM G/ATOR under PEO Land Systems
 - USMC M-P Manager: Dave Dawson
 - G/ATOR Prime Contractor: NGES
 - US Navy M-P Manager: Ms. Oreta Stinson
- Minority Institution
 - Florida International University, Miami, FL
 - Technical Lead: Dr. Kinsey Jones





CME Overview

3

Custom Power Supplies



PDUs & Panels



IPMDS Family



Embedded Power Assy



Towable Solar Farm & Mobile Charging Systems



- Mature and robust small business (WOSB and SDB) located in Tampa Bay, Florida's 10th Congressional District. Dr. Nancy Crews, President/Founder
- Located in modern 49K sq ft Development & Manufacturing Center. Integrated design to MIL qualification capabilities
- Registered ISO 9001:2008 / AS9100:2004 by NSF. A Supplier Excellence Alliance (SEA) participant. ITAR experienced
- Develop organic products and products for others. Excel in build-to-spec work for turnkey design, test, and production deliveries
- Focus: Integrated Power Supplies, Power Management and Distribution, Remote Ground Sensors, Embedded Sensors, and Test and Support Equipment
- Proven electronics and electromechanical fabrication and assembly operations. Skilled in build to specification projects
- Customers include all military services, prime and lower tier contractors, and other industries. A supplier to military, Lockheed Martin, Northrop Grumman, General Dynamics, and others
- Successful SBIR/STTR R&D participant since 1998. 15 Phase I and 9 Phase II projects with 7 Phase III transitions to date

Sensor Products



F-16, F-35, EA-18G Components



Hardware for Primes



Custom ATE or GSE



Why did CME participate in the M-P Program?



4

BUSINESS STRATEGY

- Develop a long term strategic relationship with prime contractor
- Win new business to grow company revenue and jobs
- Grow DoD awareness of CME and its capabilities and core competencies
- Increase probability of win by developing a CME “past performance” profile and standing within prime contractor’s supply chain to increase opportunities on their programs of record

TECHNOLOGY STRATEGY

- Broaden CME’s power supply product lines, especially in emerging phased array sensors and airborne/avionics subsystems
- Enhance CME supplier capabilities (technology, design and business tools, equipment, market and domain knowledge)



Program Scope



5

Business Assistance

- ERP Implementation

Technical Assistance

- Enhance CME's Power Supply, Design and Manufacturing Capability (EA-18G, G/ATOR, AMDR programs)
- Improve Risk Management, and Power Supply Design and Simulation/Modeling Tools
- Technology Transfer (Power Supply topology collaboration, Planar Magnetics design training and tool, EMI Screening Lab concept technical review)

Material Acquisition Support

- Acquire NGC surplus equipment to enhance CME Capabilities



Success Factors



6

Business Assistance

- Current NGES PM brings strong knowledge, extensive network, and savvy skills to the program
- Increased upper management awareness and support of M-P Program at NGES
- ERP provides CME better cost control and management of larger value contracts – DELTEK Costpoint PO

Technical Assistance

- Enhanced power supply design and topology knowledge, design tools, and stronger requirements verification and qualification/test capabilities
- Design capabilities and confidence of CME Power Supply design team has grown significantly
- Opportunities for long term relationship on NGES programs (USMC G/ATOR, Navy EA-18G, Navy AMDR)



Success Factors



7

Material Acquisition Assistance

- Surplus equipment transfer from NGES brings added capabilities
 - Electronic Test Equipment
 - Thermotron Chambers
 - EMI Absorbent Material
 - Furniture

Sponsor Assistance

- Strong support and engagement by Navy Small Business Program office
- Active involvement of G/ATOR Marine Corp Program Management in Mentor-Protege Agreement.



Success Detractors



8

Business Assistance

- 3 Program Managers for Mentor in first 18 months
- Minimal awareness and understanding of M-P program at NGES supply chain or programs; including subcontracting authority or other tools to use
- Integration into NGES Supply Chain missing
- No subcontracts awarded to protege to help offset high costs of protégé's investment in all aspects of agreement

Technical Assistance

- Technical community continuously misunderstood their role in program – initially not supportive
- Misaligned Technical Objectives between NGES, CME and FIU



Lessons Learned – Recommendations

9

Business

- Be a current supplier to the prime contractor before entering a M-P agreement
- Ensure a strong, commitment by Mentor (top management and supply chain) and Protege before initiating an agreement
- Mentor should select a savvy-skilled program manager who has impact authority, and a strong network within prime's programs, technical community, and supply chain management
- Protégé needs to be prepared to make a significant investment (\$ and resources)



Lessons Learned – Recommendations

10

Technical

- Bring technical community into writing the M-P proposal so they understand and buy into the program, technology transfer, etc.
- Integrate technical community – Mentor and University into kickoff meeting so everyone understands roles and responsibilities

Overall

- Use constant pressure applied relentlessly to make program a success

Contact Information

11



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**Dr. Nancy Crews
President
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**Fred Munro
Vice President
(727) 547-9799 Ext 1806
(727) 541-8822 Fax**



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MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Marine Corps Systems Command Product Group 10 Information Systems and Infrastructure Small Business Opportunities



**Ms. Karen M. Davis
Director, Product Group 10**

14 December 2011

The intent of this brief is to provide a venue for the Government and Industry to exchange general information.

Any remarks by Government officials participating in today's proceedings are not and should not be considered as a guarantee of the Government's course of action in executing current or future acquisitions and procurements actions.

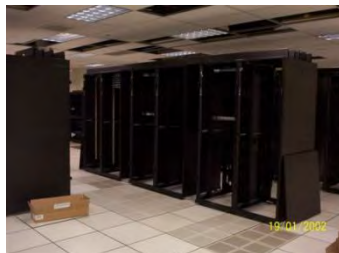
UNCLASSIFIED





Mission: Serve as the USMC's agent for design, acquisition, and sustainment of the Information Systems and Infrastructure (IS&I) used to accomplish the Marine Corps Warfighting Mission.

Vision: Be the recognized leader in delivering forward-focused information technology solutions and capabilities.

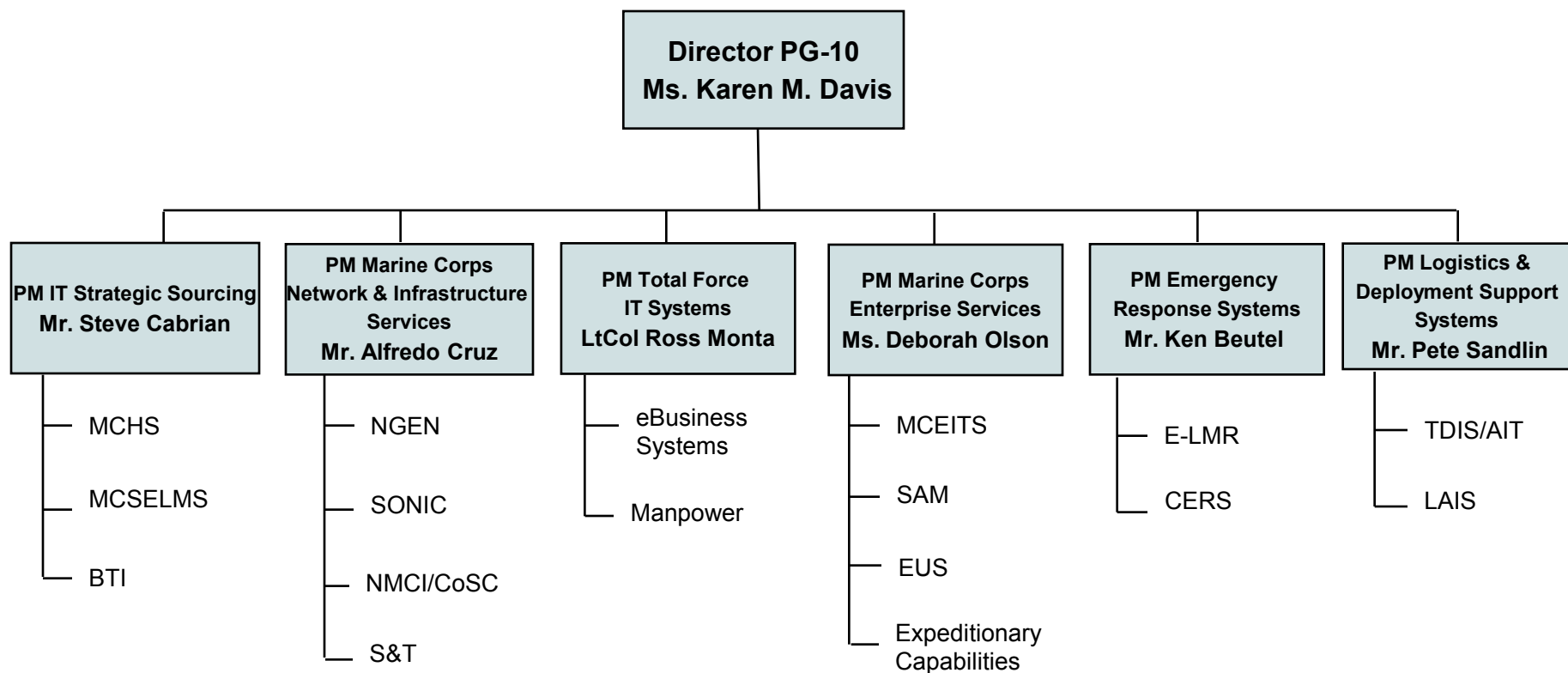




MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Director PG-10 PM Structure



Acronyms

Marine Corps Hardware Suite (MCHS)
Marine Corps Software Enterprise License Management System (MCSELMS)
Base Telephone and Infrastructure (BTI)
Navy Marine Corps Internet (NMCI)/Continuity of Services Contract (CoSC)
Next Generation Enterprise Network (NGEN)
Secure Operational Network Infrastructure and Communications (SONIC)
Standards & Technology (S&T)

Marine Corps Enterprise Information Technology Services (MCEITS)
Strategic Applications Management (SAM)
MCEITS End User Services (EUS)
Enterprise Land Mobile Radio (E-LMR)
Consolidated Emergency Response System (CERS)
Transportation and Distribution Information Systems (TDIS)
Legacy Automated Information Systems (LAIS)

UNCLASSIFIED





- Information Technology Strategic Sourcing (ITSS): MCHS and MCSELMS currently have no specific small business set-aside provisions.
 - The MCHS Team purchases COTS IT hardware (H/W) for Marine Corps customers including Programs of Record, deploying units, and various commands in the Supporting Establishment.
 - Currently operate off of the Army's CHES contract with pre-selected vendors.
 - Planned Marine Corps follow-on H/W contracts are in work, but have no set-aside provisions.
 - Non-catalog items use general postings against GSA schedules, small businesses can bid on these specific procurements.
 - The MCSELMS Team manages the strategic sourcing initiative that maintains and supports the Marine Corps evolving enterprise software investment as an integrated portfolio. The concept of enterprise licensing is based on commercial best practices and focuses on reducing the total ownership costs and increasing ease of use and license management. As much as practical, working towards consolidated enterprise agreements.
 - COTS products are purchased from authorized resellers under DoD ESI contract vehicles as required by DFARS 208.7402.
 - Small Businesses who are authorized resellers will have opportunities to bid.





- Total Force Information Technology Systems (TFITS): Current 8a set aside for Portfolio Management is up for re-compete in FY13. Efforts include analysis, management and engineering support associated with current and continually changing acquisition statutes and regulations. Brief description of effort as follows:
 - Provide support to assess, implement, and manage a standardized set of acquisition, development, and operational practices across the TFITS portfolio.
 - Establish a formal IT portfolio management process and support critical aspects of the TFITS portfolio to deliver measurable business value.
- Emergency Response Systems (ERS): Potential areas in late FY12 or FY13 as follows:
 - Land Mobile Radio Equipment Installation: ERS will be procuring COTS land mobile radio components (radio subscriber units, repeaters) from major manufactures and provide them as Government Furnished Equipment (GFE) for installations to install within vehicles, radio frequency sites, and other locations. Qualified sources (vendor certified) may be used in bases located in Virginia, North Carolina, South Carolina, Georgia, Florida, California or Arizona.
 - Dispatch Center Configuration: Emergency dispatch centers will be equipped with modern Enhanced 911, Computer Aided Dispatch, and ancillary systems. Qualified sources familiar with National Emergency Number and National Fire Protection Association best practices may be used to provide configuration management and support for various centers located in Virginia, North Carolina, South Carolina, Georgia, Florida, California or Arizona.





- Marine Corps Enterprise Services (MCES): Currently, PM MCES has no requirement for additional 8a set asides, but there are numerous 8a set aside contracts in place. Efforts include analysis, management, modeling and simulation, training, and engineering support associated with current and continually changing acquisition statutes and regulations.
- The first opportunity for PM MCES 8a set aside re-compete will be FY13. Brief description of efforts:
 - Provide support to assess, implement, and manage a standardized set of acquisition, development, and operational practices across the MCES portfolio.
 - Provide program management experts to support management, logistics, and engineering of rapid development projects and large scale IT initiatives.
 - Provide modeling and simulation of Marine Corps networks against user requirements to better define requirements and hardware specifications.
 - Provide training support to users of specific systems and software applications required to effectively operate the systems.
 - Provide engineering support in the design and/or redesign of systems to optimize hardware and software efficiencies and to streamline requirements.



Global Combat Support System- Marine Corps (GCSS-MC) PDSS

Small Business Conference Fredericksburg Conf Center

December 14, 2011



Andrew Dwyer
Program Manager
GCSS-MC

GCSS-MC Block 1 Program Overview

Updated 28 Nov 2011

Program Description

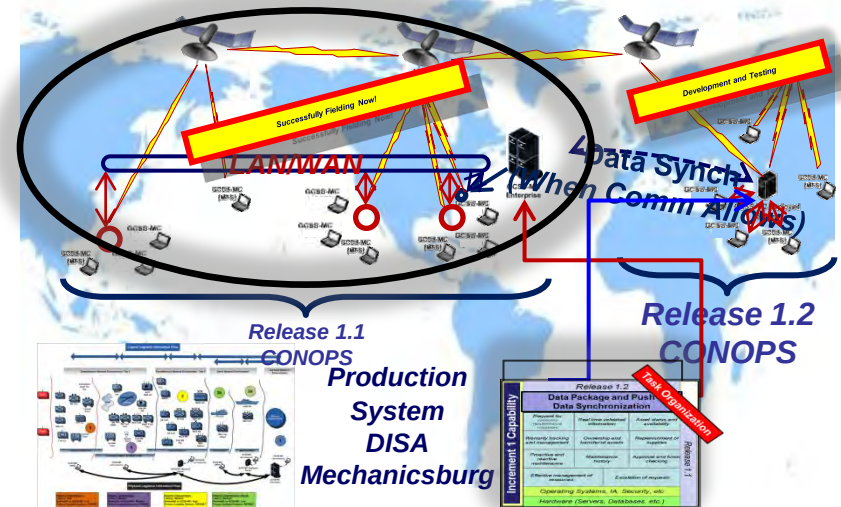
Primary technology enabler for Marine Corps LogMod strategy.

Portfolio of legacy and modern logistics apps providing MAGTF Supply/Maintenance functionality. Core is modern, COTS enterprise resource planning software (Oracle 11i e-Business Suite). Enables Marines to operate while deployed with reachback from the battlefield.

Being implemented in increments. **Increment 1** replaces 40-year old legacy supply and maintenance IT systems. **Future increments** will enhance capabilities in **Warehousing, Distribution, Logistics Planning, Decision Support, Depot Maintenance, and Integration** to improve asset visibility.

- Full Deployment retires 4 Legacy Systems

Increment 1 Architecture



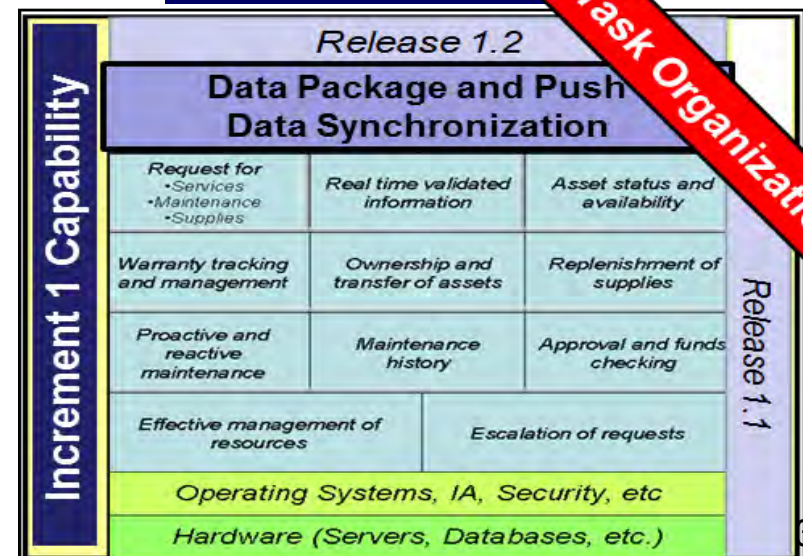
APB Milestones

Milestone	Block 1 Baseline	
	Objective	Threshold
Milestone A	Jul 2004*	Jul 2004*
Milestone B	Jun 2007*	Jun 2007*
Milestone C	May 2010*	Nov 2010
Full Deployment Decision (FDD)	Jan 2012	Jul 2012
Full Deployment (FD)	Jan 2013	Jul 2013

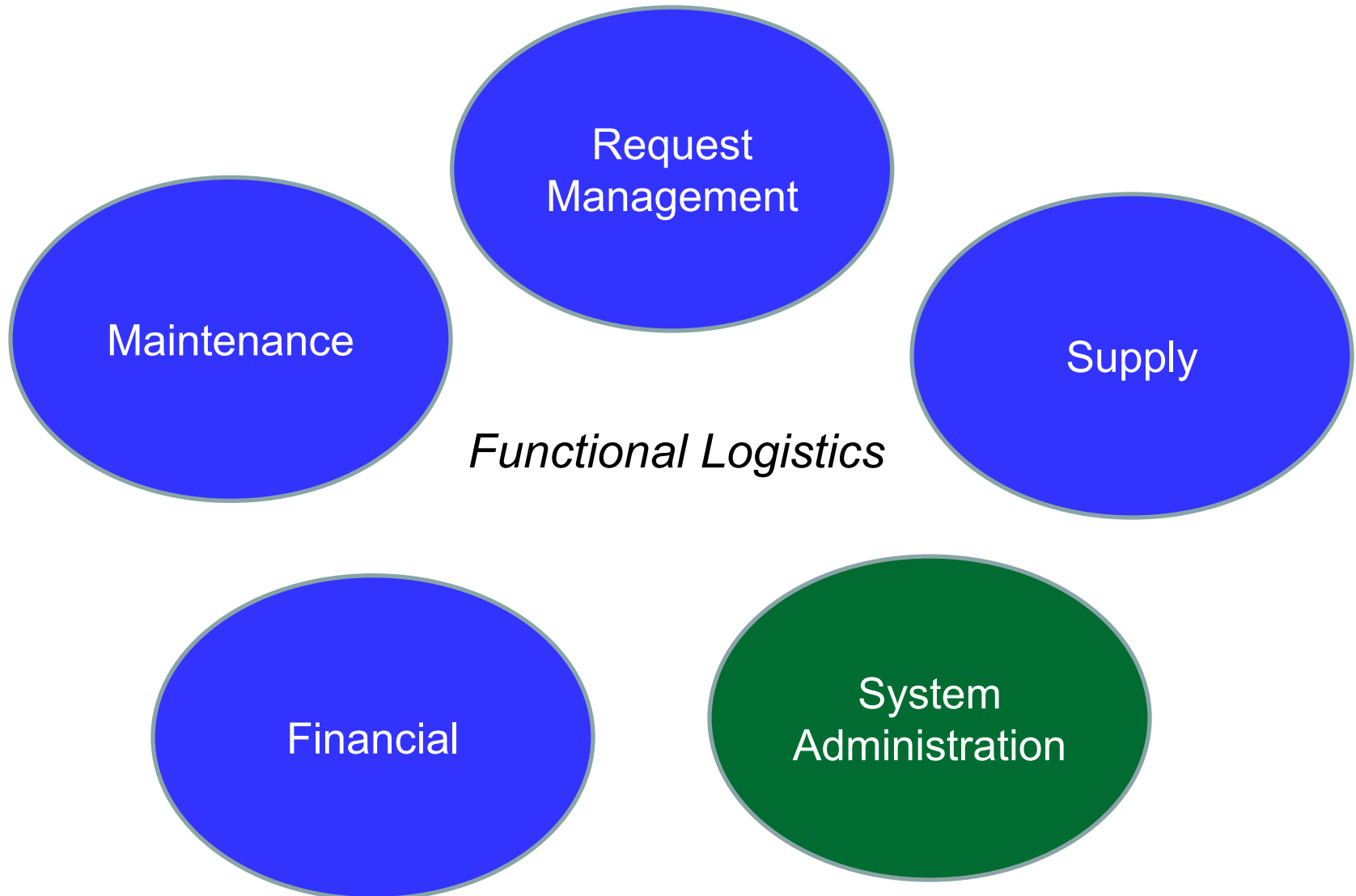
APB - Approved 29 Apr 2010

* Denotes actual date achieved

Increment 1 Deliverables



Increment 1 Capabilities



Request Management

- **Request and track status of products and services**
- **Route, coordinate, task and track orders through fulfillment**

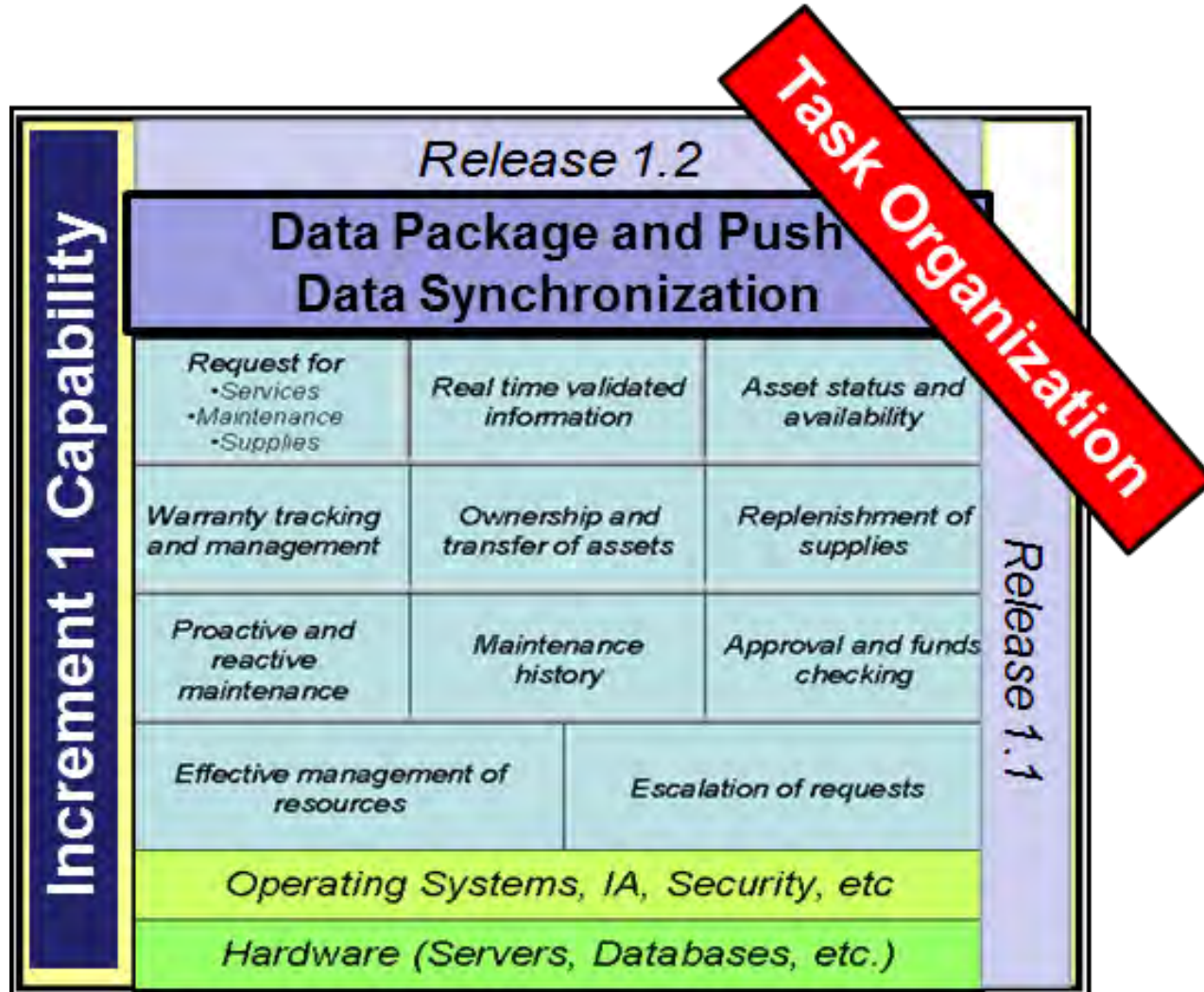
- **Plan what is held, quantity, where and set reorder points**
- **Plan and forecast consumption of products & services**
- **Manage inventory capacity, resources and control**
- **Manage inventory operations**
- **Receipt and processing for warehouse operations**
- **Asset management**
- **Customer order Management**
- **Distribution operation management**

- **Planning**
- **Capacity**
- **Operations**
- **Scheduling**
- **Fulfillment**

- **Capture costs and other financial data related to inventory and asset values required to obtain a clean audit opinion**

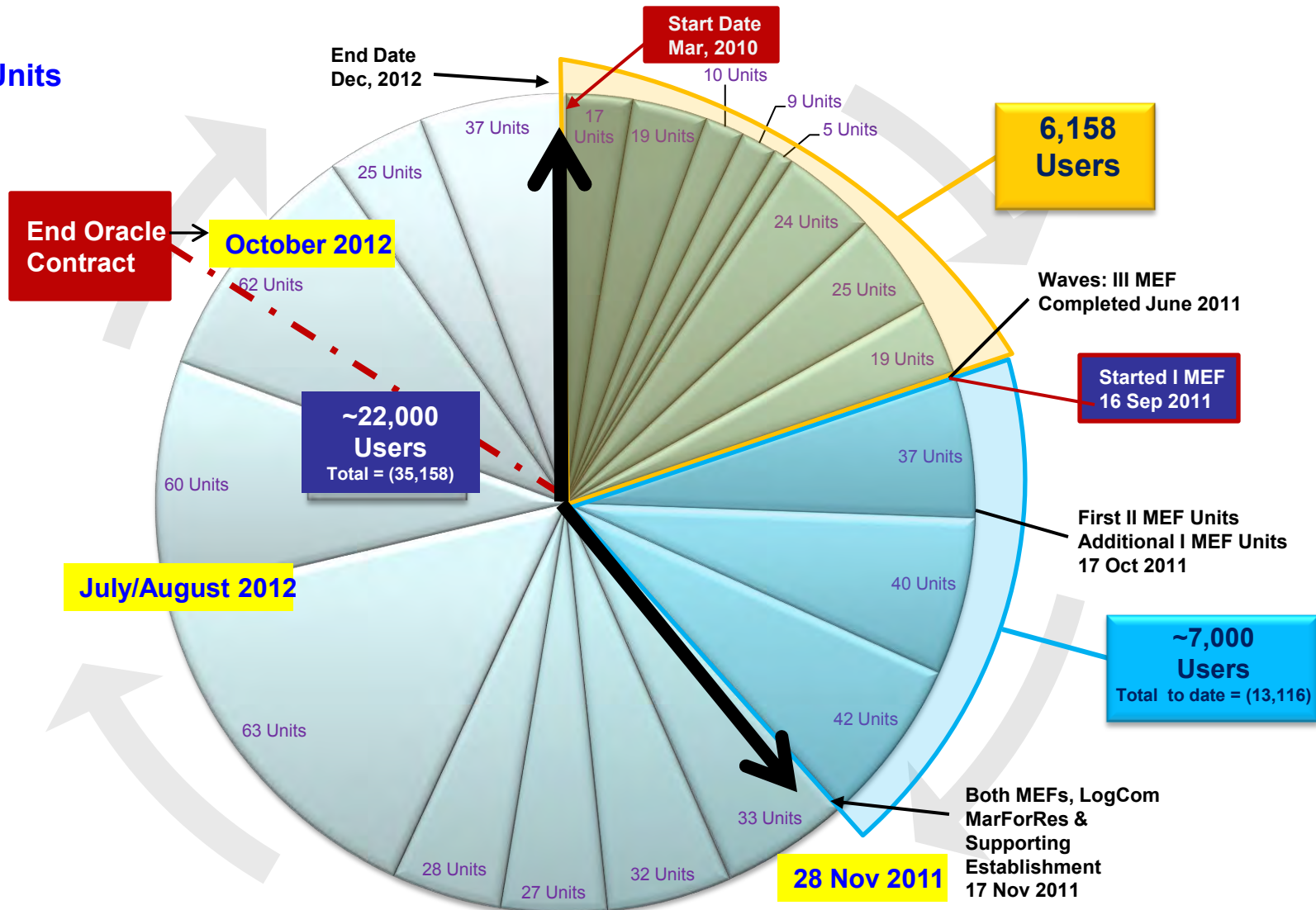
- **Customer planning based on consumption of services**
- **Task Organization**
 - Ability to maintain a task organization specifying which units are supported by which service providers. Allows task organizations to define how requests are routed and data synchronized among multiple deployed capabilities. Administrators and managers with permission can define and modify task organizations. The system also performs Capital Asset accountability tasks
- **Workflow management, business rules and processes**

GCSS-MC Capabilities



Total Force Implementation (Release 1.1) Timeline

**Total # Units
614**



Mission Statement
To Enable a MAGTF to Use GCSS-MC Anywhere

Deployable Environment*

- GCSS-MC Deployable Cases (GDC)
 - Threshold – 7 / Objective – 11
- ~~GCSS-MC Deployable Shelter (GDS)~~

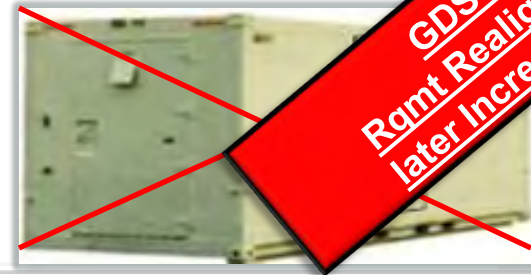
* GCSS-MC LCM Inc 1 CPD v3.2 (JROCM 018-10) – 28 Jan 10

Key Capabilities

- Task Organization from Enterprise to GDC
- Deployed Access (Data Synchronization)
- Mobile Field Service (MFS) Computer Application
- (2) FSRs accompanies GDC (garrison & deployed)

GCSS-MC Deployable Shelter (GDS) Operational Characteristics

- 1500 concurrent users
- Servers in ISO Certified Shelters



GCSS-MC Deployable Cases (GDC) Operational Characteristics

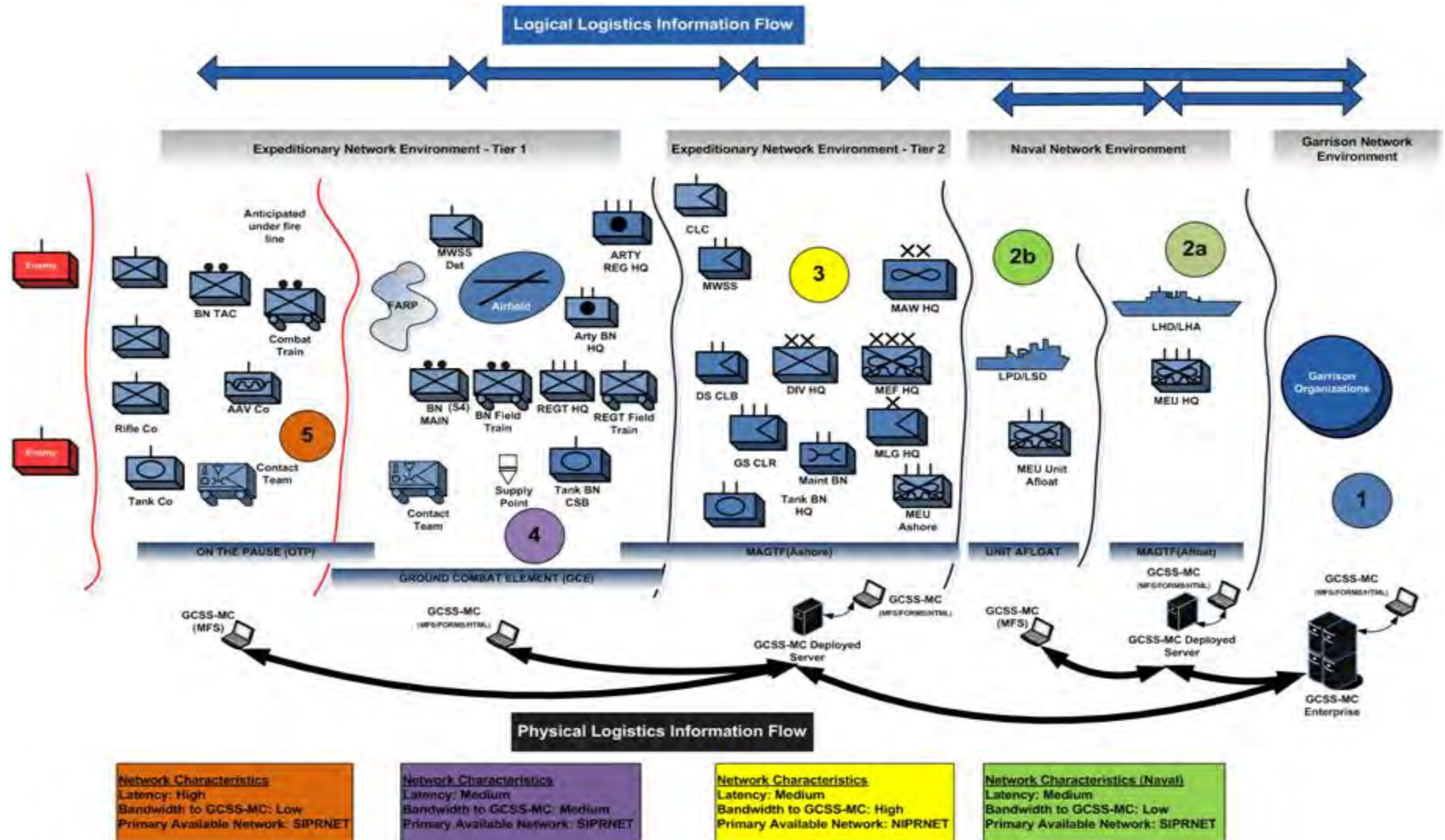
- 150 concurrent users
- ~110 lbs per case; 660 lbs total
- Two-man portable



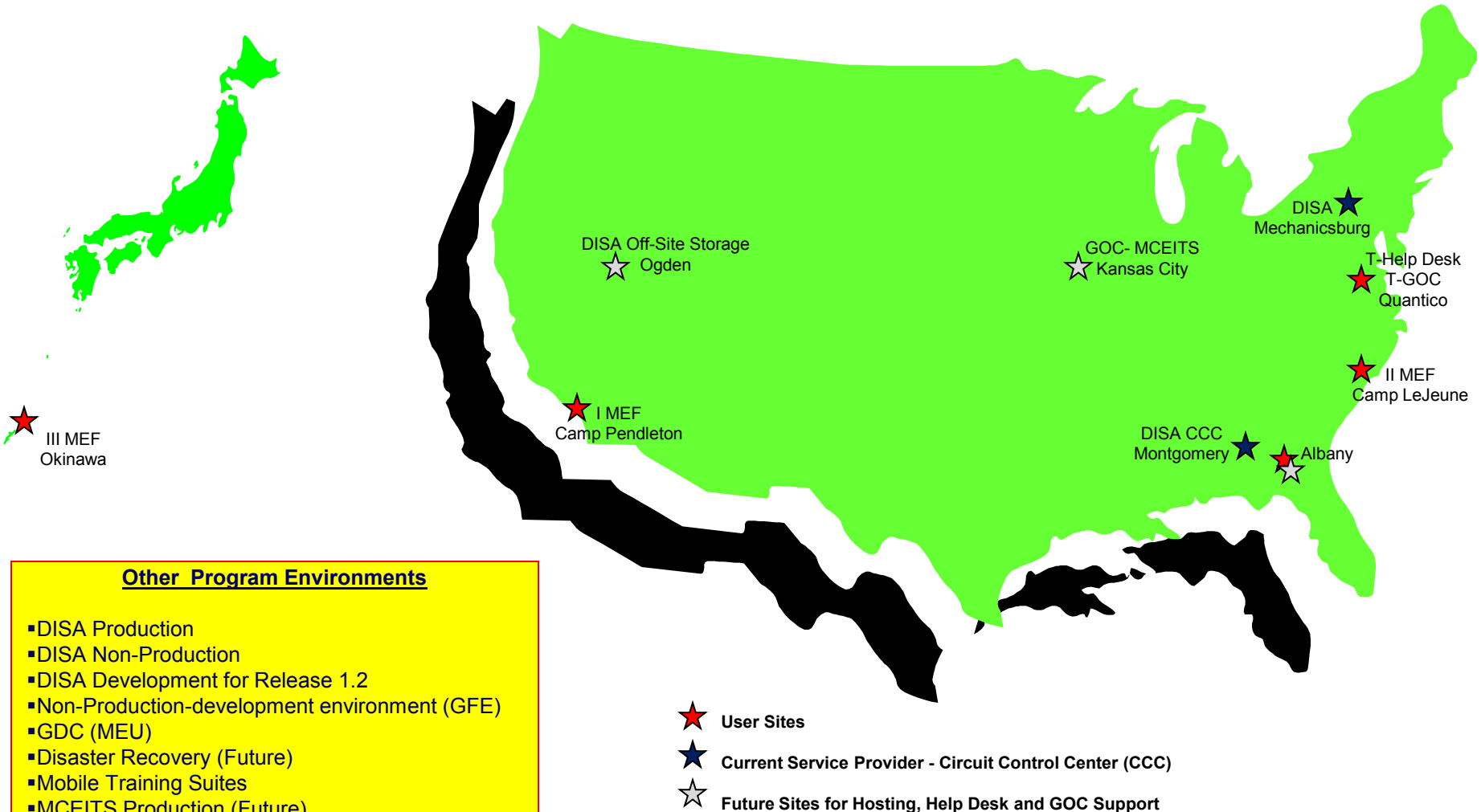
(8) LHD Ship Alteration



GCSS-MC Operational Environments



Post-Deployment System Support Concept



Solicitation Overview

- **Full and Open Competition, Performance based**
 - SOO will be provided with solicitation
 - PWS desired as part of proposal
- **All communications concerning the RFP and the solicitation must be directed to the Contracting Officer, David Berry**
- **All Correspondence regarding this solicitation shall be submitted via email to “mcsc_isi@usmc.mil” and shall reference solicitation number M67854-12-R-4682**
- **Best Value Evaluation Methodology**

- **Contracting Strategy: Single IDIQ contract**
 - 5 year ordering period
 - Minimum per annum: In RFP
 - Maximum per annum: In RFP
 - Flexibility to Issue multiple task orders as Performance Work Statements
 - Flexibility with task order type

- **Small Business Target: 25%**

- **Notional Schedule**
 - **Solicitation Issued December 2011**
 - **Proposals due January 2012**
 - **Contract Award April 2012**

- **Programmatic Support**
- **Technical Management Support**
- **Configuration Management Control**

Service Support Model

- **GCSS-MC users supported by a layered infrastructure**
- **Upon categorization and prioritization user problems are dispersed for resolution to specialized skill based support tiers**
- **The following (5) levels or “Tiers” make up the GCSS-MC supporting infrastructure within the GCSS-MC Enterprise Service Desk**

What is PDSS?

PDSS Program Transition To GCSS-MC Increment 1

- All necessary maintenance and sustainment activities for the GCSS-MC system in production**
- Sustainment activities include using a Failure Reporting, Analysis and Corrective Action System (FRACAS) program, configuration management processes, and sustainment plan**
- Service Desk:**
 - 365 by 24x7 Service Desk operations supporting Tiers 0-3**
 - Tier 1 is 24x7 / 365 - FFP**
 - Tier 2 and Tier 3 – FFP and will require scheduling adjustments commensurate with similar large scale ITSM efforts**

PDSS

Overview Responsibilities

- **GCSS-MC PDSS Includes:**
 - **GCSS-MC Deployable Cases (GDC)**
 - **Systems Development Environment (SDE)**
 - **Application Availability of Production Support System (PSS) DISA**
 - **Application Availability of Deployment Support System (DSS) DISA**
 - **Application Availability of Production System DISA**

- **PDSS Team (contractor and government) will be organized per ITSM Model-using ITIL V3**

- **GCSS-MC Block 1 in the process of conducting a Business Case Analysis to determine best Performance Based Logistics (PBL) Approach utilizing the following **Total Life Cycle Systems Management** metrics:**
 - Operational Availability
 - Operational Reliability
 - Logistics Response Time
 - Cost per Unit Usage
 - Logistics Footprint
- **The PDSS Contractor Shall serve as a PSI responsible for all environments within GCSS-MC (Enterprise and Deployable Systems)**
 - Warranty Management
 - Maintain accuracy of Technical Publications
 - The following Working groups are established within the PMO and must continue to be supported through PDSS
 - ESOH
 - RAM
 - HSI
 - DMSMS
 - Maintenance Support and GFE Management of Deployable Systems

- The PDSS Contractor shall be responsible for:
 - Management and DBA support for Training Deliver Devices:
 - Currently at MEFs, LogCom, and MFR PMO uses Mobile Training Suites
 - Future plans may dictate use of Regional TECOM and/or Enterprise training content devices



Mobile Training Suite

GDC Physical Characteristics

Component	L (inches)	W (inches)	H (inches)	SQFT	CUFT	Weight (lbs)	Person Lift	Person Carry
GNPB	37.6	22	9.6	5.27	4.68	99	3	3
GNSB						120	4	3
GNUB						115	4	3
GSPB						120	4	3
GSSB						120	4	3
GSUB						88	3	2
GAB	29	18	10.5	4.48	4.7	55	2	2
GDC System	37.6	44	39.3	10.54	32.78	743	N/A	N/A

Operating Temperature	50° - 95° F
Storage Temperature	(-)4° to 122° F
Power	2 x NEMAL L-20R, 20A, 120V
Current Power Requirement	1127W/ 9.4A
Future Power Requirement	1209W/ 11A



FSR Support Requirements

GCSS-MC Deployable Cases & Shelter

- **The GDC System, when deployed, shall be operational and available 24/7 to support deployed mission operational requirements of the Warfighter**
- **The contractor shall provide qualified FSR's to support CONUS and OCONUS exercises in support of Marine Air Ground Task Force (MAGTF) Command Elements deploying from the Eastern and Western Continental United States as well as within the Western Pacific Islands of Hawaii and Japan where United States Military bases are stationed**
- ***System and Application Operation***
- ***FSR Help Desk***
- ***Software Installation***
- ***Software Change Request (SCR)***
- ***Configuration Management Control***
- ***Metrics***
- ***Application Software***

Ship Change

- **SCD #5380:**
- **Installation of a support unit to hold six component cases and one (1) accessory spares case**
 - One (1) shelf unit
 - Power and LAN Drops
- **Marines carry the system aboard in six (6) component cases / one (1) accessory spares case and Install/Operate/ Maintain (IOM) the system while afloat**



****FSRs will deploy aboard ship with the MEU***

- **Critical function within GCSS-MC**
 - Information Operations that protect and defend information and information systems by ensuring their availability, integrity, confidentiality, authentication, and non-repudiation
- **Provides for restoration through capabilities**
 - Protection; Detection; Reaction
- **Mandated through legislation and guided by policy**

▪ Objective

- Aggressively pursue IA excellence
- Ensure GCSS-MC is always available to the Warfighter
- Information is protected from unauthorized disclosure and unauthorized modification

▪ General requirements

- Provide expertise and services for:
 - Maintaining the GCSS-MC IA Program
 - Ensuring GCSS-MC meets all appropriate federal laws and regulation, DoD, CJCS, DON, and Marine Corps IA policy and guidance

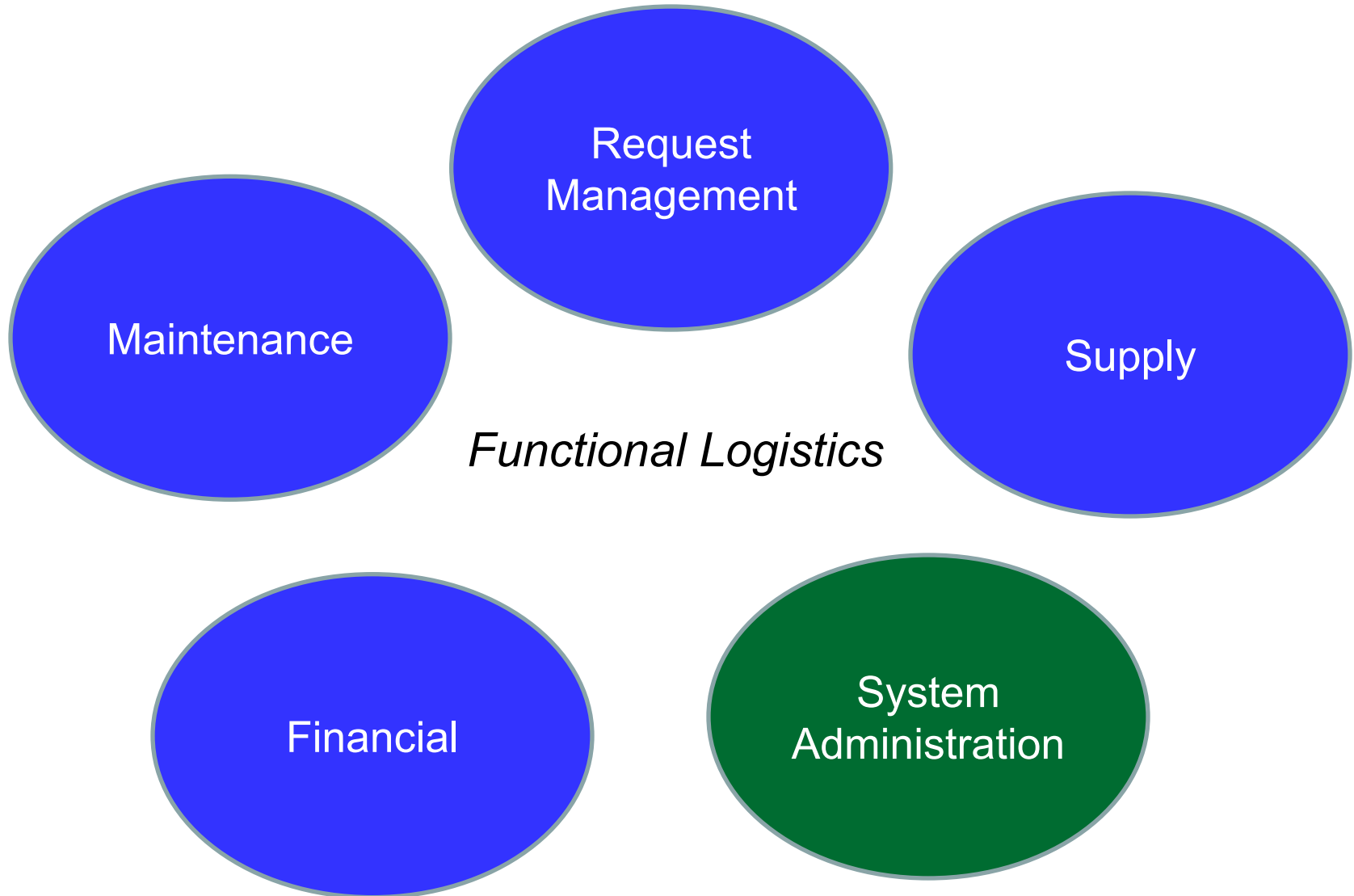
▪ End state

- Attain and maintain a USMC DAA accredited state

■ Background Investigation requirements

- Per DoDI 8500.2 and SECNAV Manual 5510.30
 - Some are NACLC, others SSBI (Role Dependent)
-
- In accordance with DoD 8570.1-M, Information Assurance Workforce Improvement Program, the contractor shall:
 - Ensure personnel performing duties and services of this task meet the initial and continuing certification requirements associated with their responsibilities
 - Must meet the certification requirements before starting work on the contract

Increment 1 Capabilities



Request Management

- Request and track status of **products** and **services**
- Route, coordinate, task and track orders through fulfillment

Supply

- **Plan what is held, quantity, where and set reorder points**
- **Plan and forecast consumption of products & services**
- **Manage inventory capacity, resources and control**
- **Manage inventory operations**
- **Receipt and processing for warehouse operations**
- **Asset management**
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Maintenance

- **Planning**
- **Capacity**
- **Operations**
- **Scheduling**
- **Fulfillment**

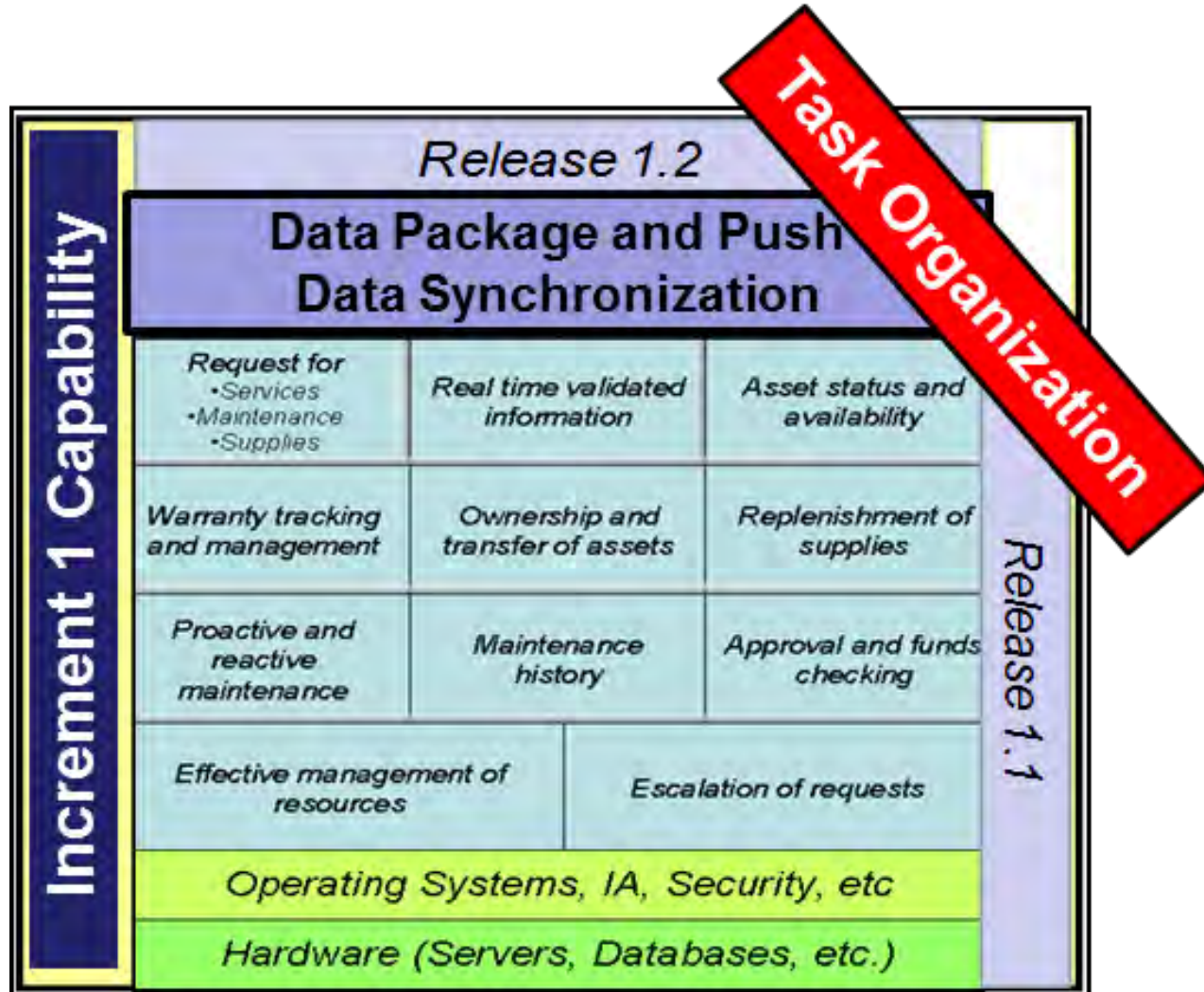
Financial

- **Capture costs and other financial data related to inventory and asset values required to obtain a clean audit opinion**

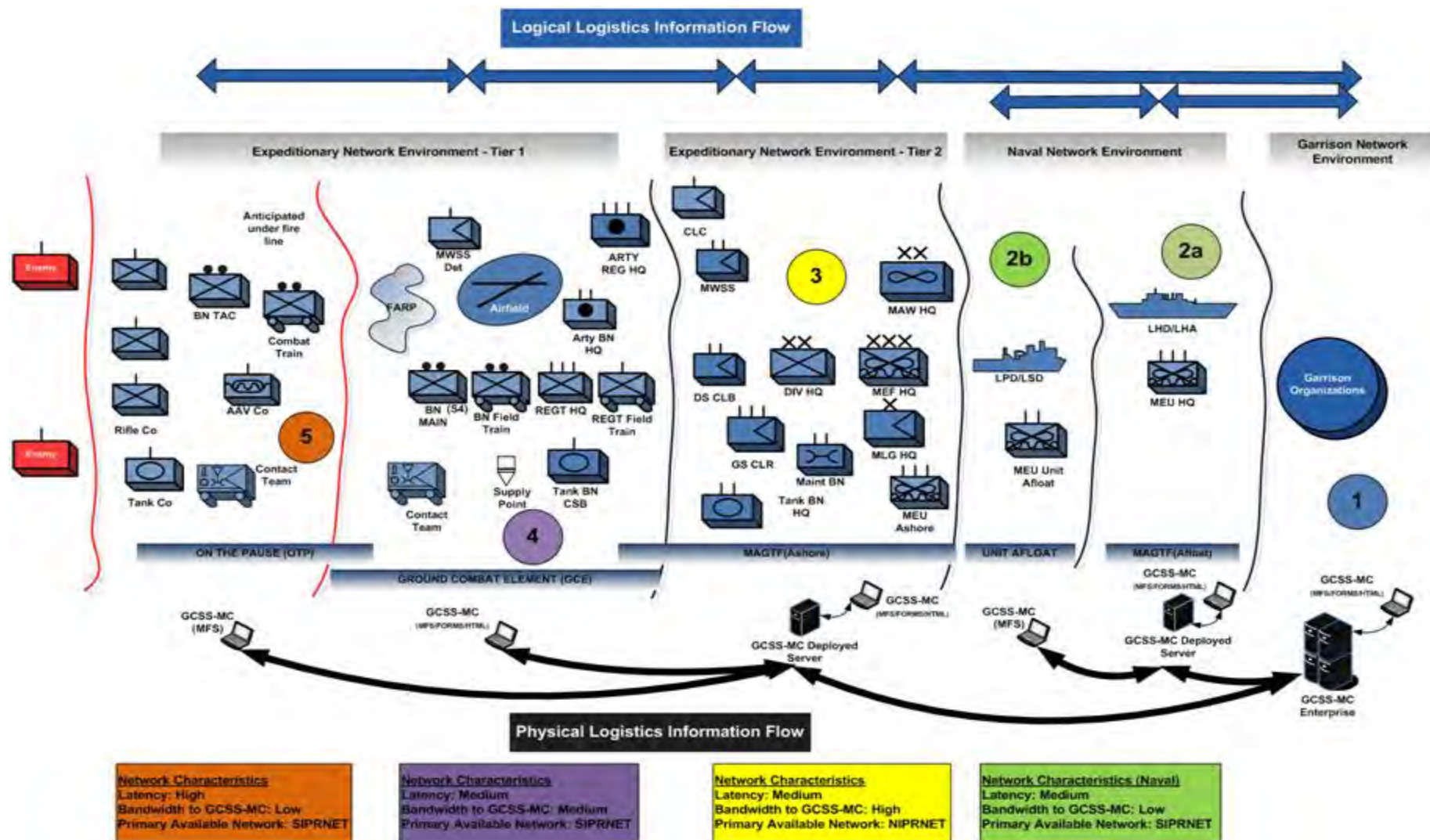
System Administration

- **Customer planning based on consumption of services**
- **Task Organization**
 - **Ability to maintain a task organization specifying which units are supported by which service providers. Allows task organizations to define how requests are routed and data synchronized among multiple deployed capabilities. Administrators and managers with permission can define and modify task organizations. The system also performs Capital Asset accountability tasks**
- **Workflow management, business rules and processes**

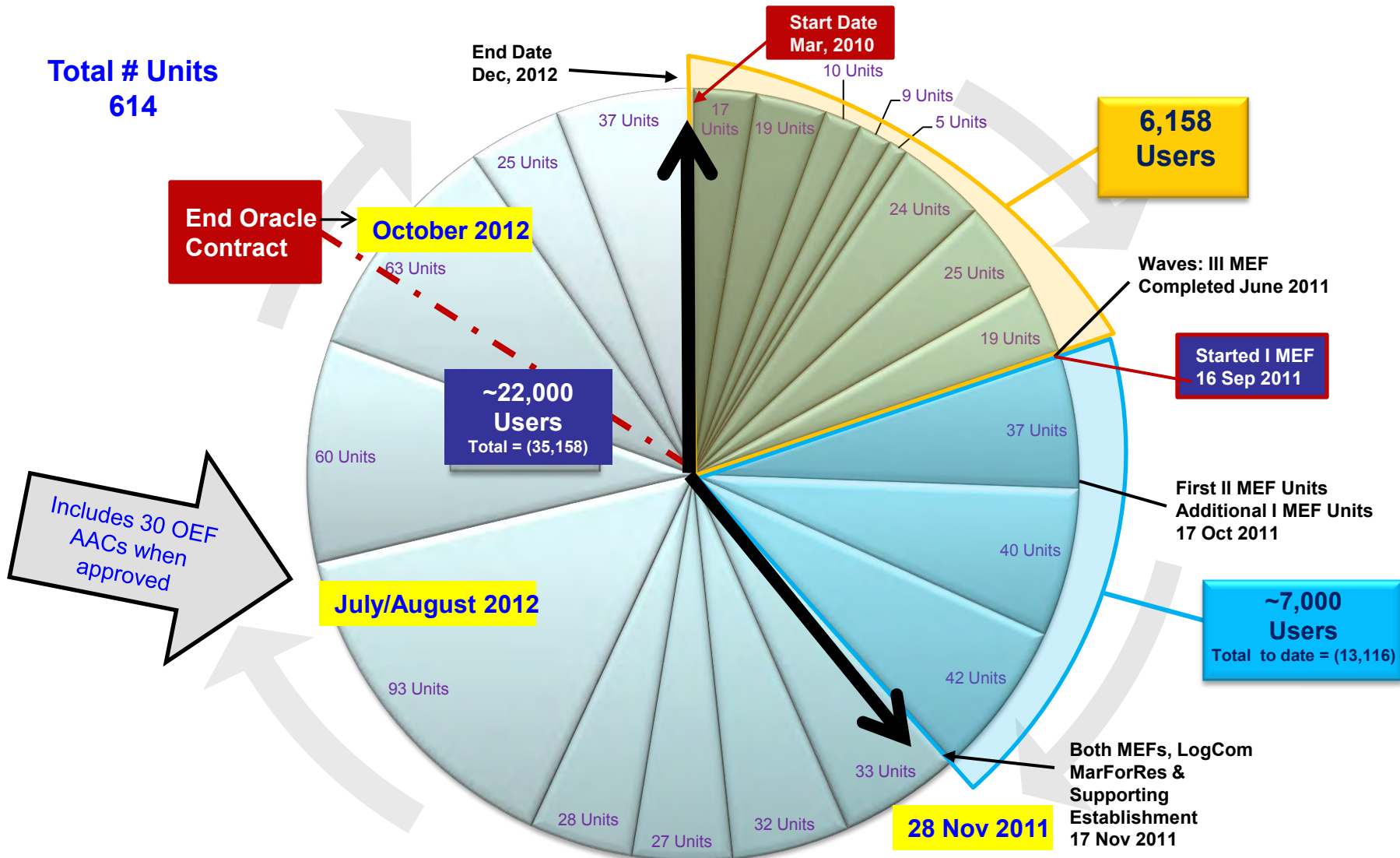
GCSS-MC Capabilities



GCSS-MC Operational Environments



Total Force Implementation (Release 1.1) Timeline



Release 1.1 Operations

- **Requires robust communications architecture**
- **Provides full set of GCSS-MC functionality**
 - Enterprise-level shared data environment
 - Advanced Supply Chain Planning
 - Application Extensions (rich robust reports)
 - Task Organization
 - DISA managed services and systems support
 - Centralized Helpdesk and GCSS Operations Center
- **Mobile Field Service (MFS) provides small subset of functionality for pre-loaded inventory from Enterprise**
- **Enterprise Configuration Control**
- **Enterprise Training packages**

Release 1.2 Operations

- **User still requires pathway to Enterprise or Deployed servers**
- **User transacts against Enterprise or Deployed but does not have choice to transact against either**
- **Provides limited shared data environment**
- **Many challenging operational scenarios**
- **Communications still a factor to reach Enterprise or Deployed servers**
- **Mobile Field Service (MFS) provides small subset of functionality for pre-loaded inventory from deployed servers**
- **Requires augmentation of Field Service Reps to support**

Acquisition Center for Support Services

COMMERCIAL ENTERPRISE OMNIBUS

Support Services

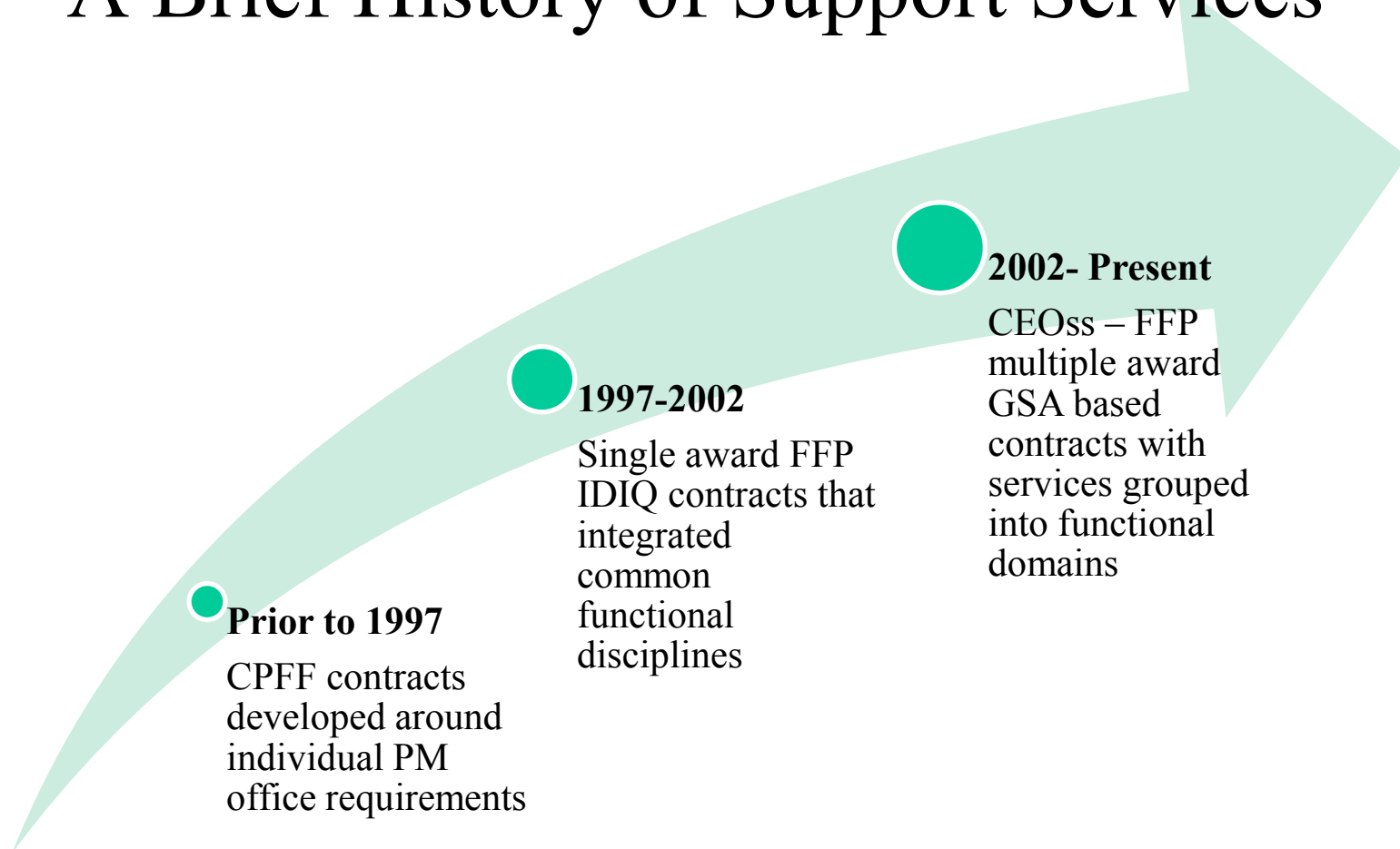


FY12 Small Business Conference

Mr. Paul Ortiz
Director, ACSS



A Brief History of Support Services





Acquisition Center for Support Services



Mission

To maintain the Acquisition Center for Support Services (ACSS) to support the Commercial Enterprise Omnibus Support Service (CEOss) Business Model as a best practice for centralized acquisition of technical and professional services for MARCORSYSCOM using a Service Center approach.



CEOss Overview

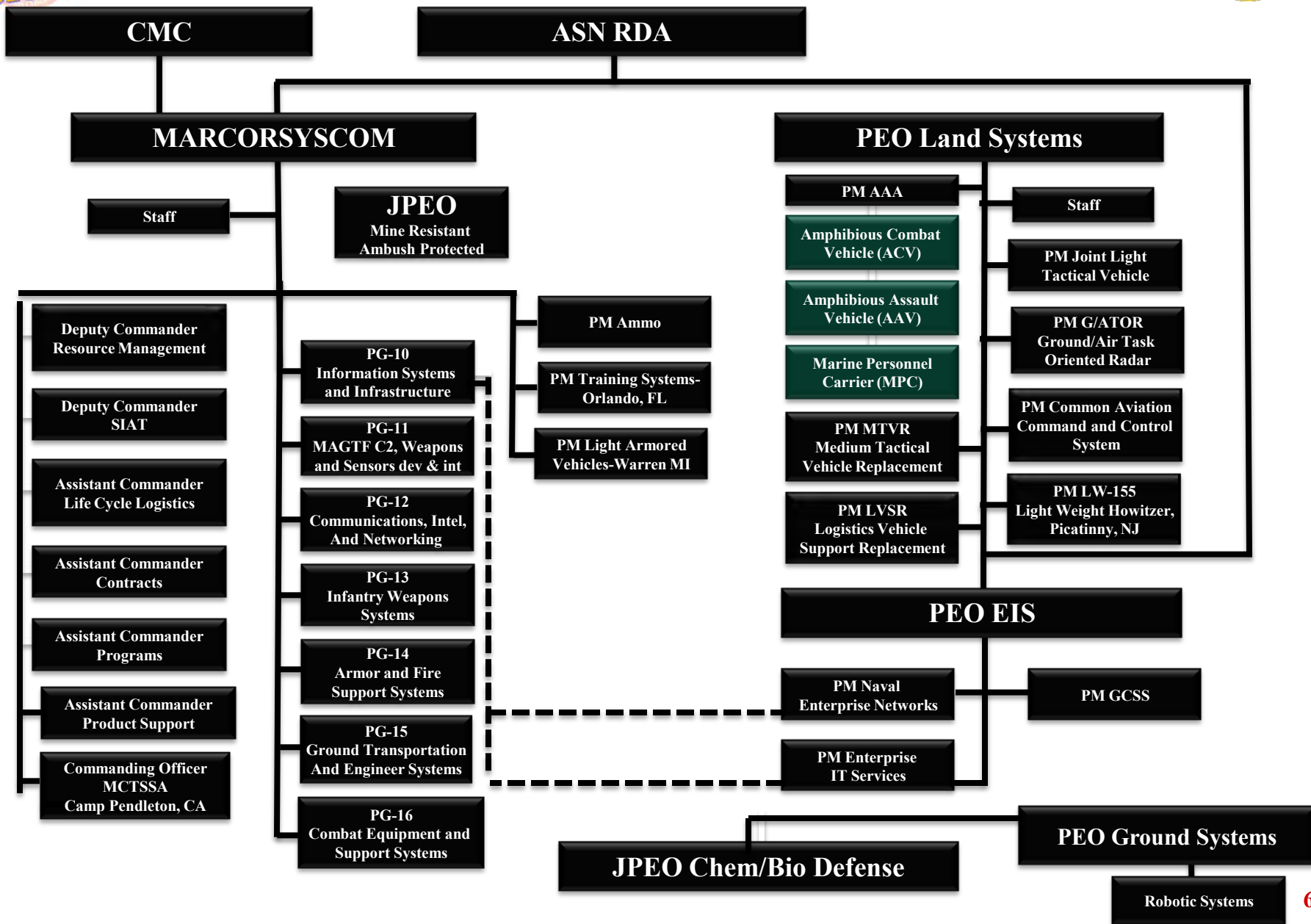


Underlying Principles

- GSA Federal Supply Schedule Awards
- GSA Blanket Purchase Agreements
- Advisory and Assistance Services
- Multi-Award competitions among BPA Holders within domains
- Maximum contract length of base year and two option years
- Streamlined Process using FAR 8.405-2 procedures
- Target award timeline of 30-40 days from RFQ release

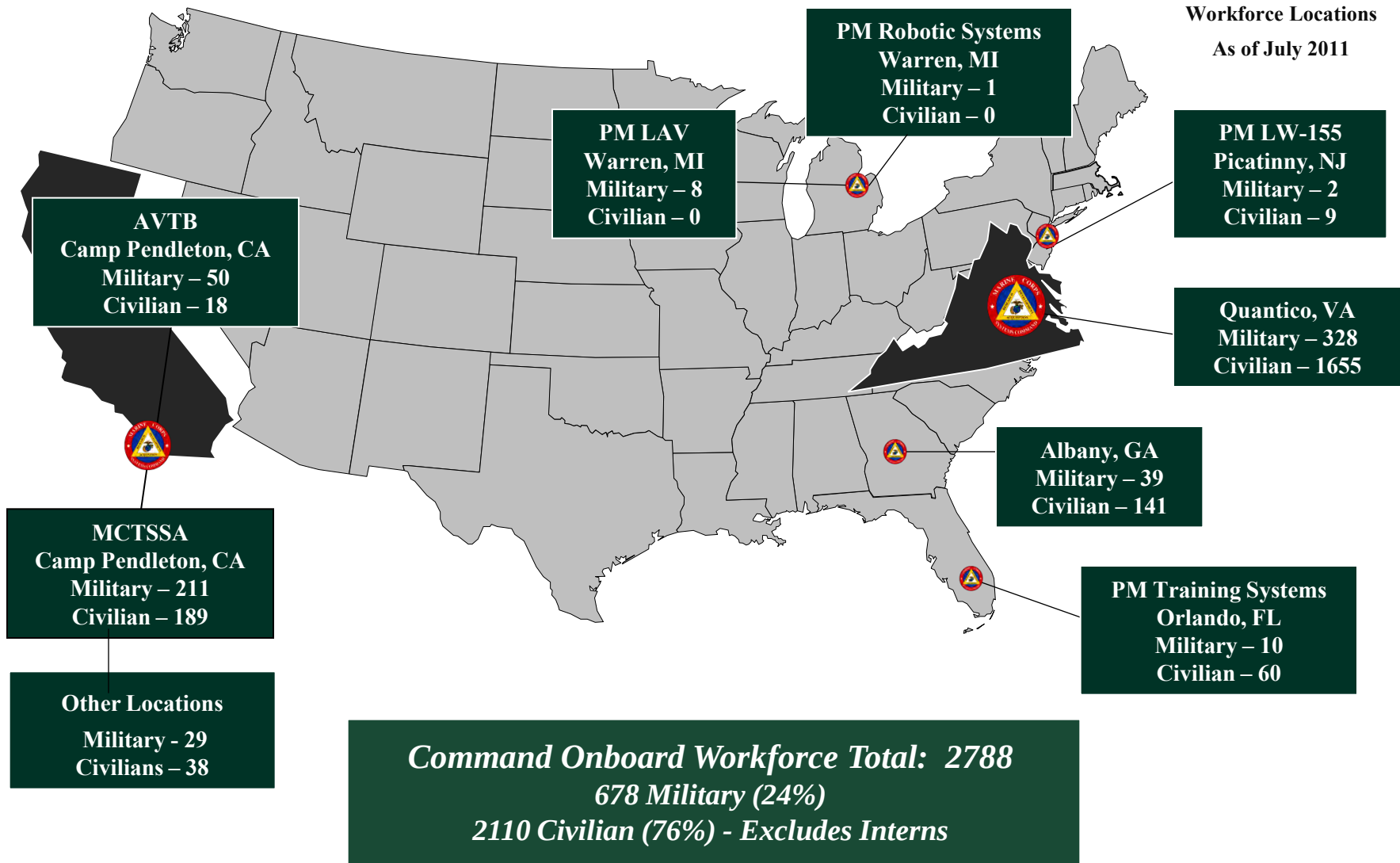


Who Does ACSS Support?





Where Are They Located?





CEOss Domain Competencies

DOMAINS

Specialty Engineering

- ☑ 874 – MOBIS
- ☑ 871 – Engineering Services
- ☑ 899 – Environmental Services
- ☑ 70 – IT Services & Support
- ☑ 873 – Lab Testing & Analysis

Business & Analytical

- ☑ 874 – MOBIS
- ☑ 520 – Financial / Business
- ☑ 69 – Training Services

Engineering & Scientific

- ☑ 874 – MOBIS
- ☑ 871 – Engineering Services
- ☑ 70 – IT Services & Support

Acquisition, Logistics & Admin

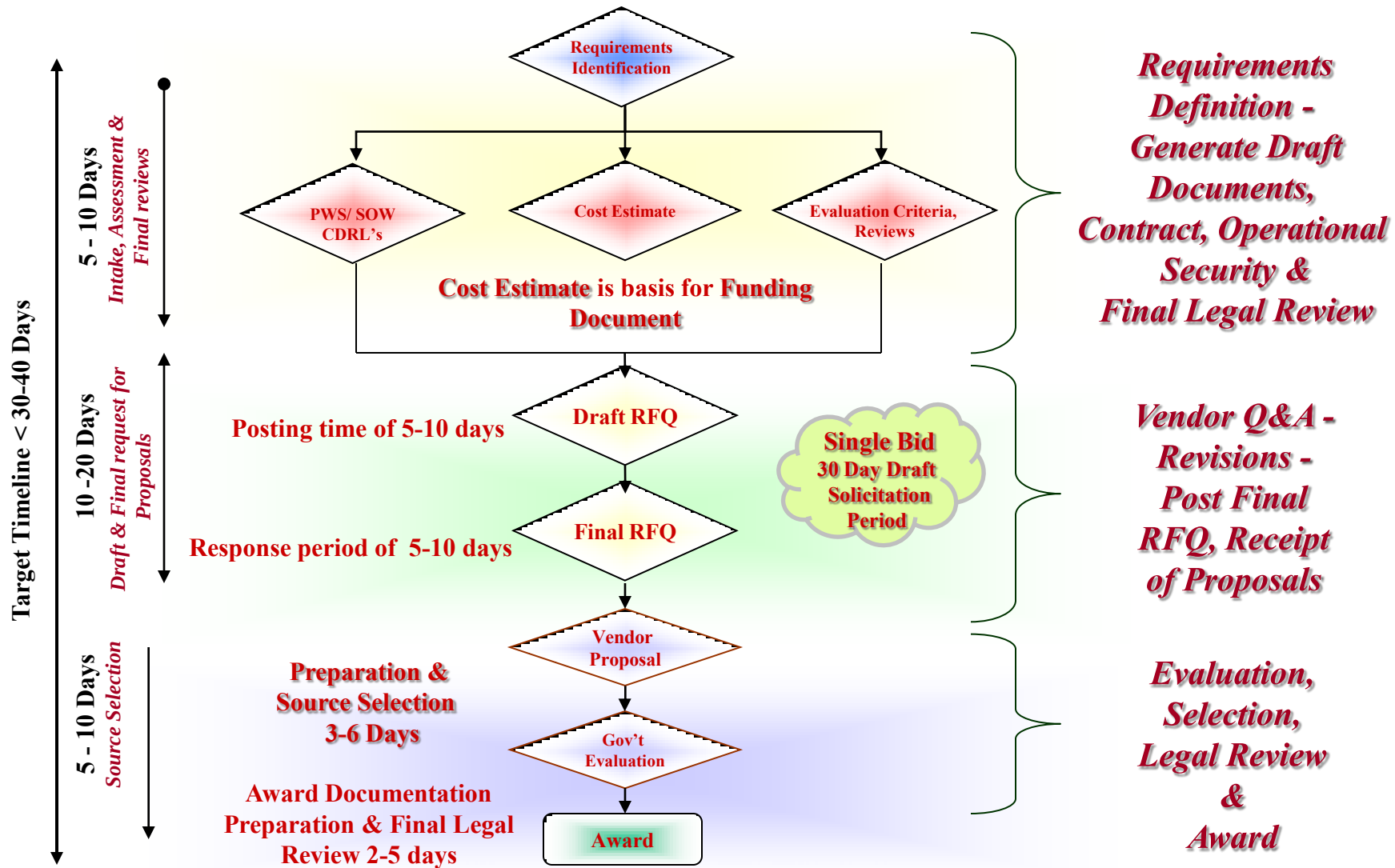
- ☑ 874 – MOBIS
- ☑ 874 V - LOGWORLD
- ☑ 871 Engineering Services

- ✓ Qualifying GSA Schedules for Prime Vendors / Selective for Teammates
- ✓ No Restrictions on Team Member Schedules within Domains
- ✓ “Open Season” - Modify Domains



CEOss Customer Process Model

Expedited Award Process





2011 ACSS – CEOss VENDORS



ES



QinetiQ

TASC

SAIC
From Science to Solutions

CACI
EVER VIGILANT

BAE SYSTEMS

JACOBS

dcscorp

Gamben
Customer Focused, Employee Driven

GENERAL DYNAMICS
Information Technology

SE

Battelle
The Business of Innovation



STANLEY

Technology Associates
International Corporation

CSC

SURVICE
ENGINEERING COMPANY

RNB
Technologies, Inc.

mtcsc

ALA

Thomas Associates Inc

Integrated Design Innovative Solutions



LOGIS
TECH

KRATOS
DTI ASSOCIATES, INC.

LOCKHEED MARTIN
We never forget who we're working for



URS

THE COLUMBIA GROUP



ITT

BA



serco



CRITICAL THINKING.
SOLUTIONS DELIVERED.

TECOLOTE
RESEARCH, INC.

KALMAN
Kalman & Company, Inc.

Booz | Allen | Hamilton



2011 Business Metrics



CEOss FY11 Domain Players

Specialty Engineering

- **FY11 Base:** 9 Prime Awards
- **Awards:** 37 TO's / ~\$50 M
- **Avg. No. Teammates per Prime:** 23
- **Primes:** AT&T, Battelle, CSC, MTCSC, RNB, Stanley, Survice, TAIC, TSC

Business & Analytical

- **FY11 Base:** 6 Prime Awards
- **Awards:** 45 TO's / ~\$42.1 M
- **Avg. No. Teammates per Prime:** 24
- **Primes:** BAH, Flatter, Kalman, MCR, Serco, Tecolote

Engineering & Scientific

- **FY11 Base:** 10 Prime Awards
- **Awards:** 56 TO's / ~\$124 M
- **Avg. No. Teammates per Prime:** 26
- **Primes:** BAE, CACI, Camber, Centurum, DCS, GDIT, Jacobs, QinetiQ, SAIC, TASC

Acquisition, Logistics & Admn.

- **FY11 Base:** 9 Prime Awards
- **Awards:** 43 TO's / ~\$121.4M
- **Avg. No. Teammates per Prime:** 29
- **Primes:** TCG, CTC, DTI, EDO, INS/LM, L-3, Logis-Tech, Thomas Assoc., URS

FY 2011 - 34 Prime Vendors/Over 350 Participating Firms



FY11 CEOss Performance

CEOss FY11 Performance Report

FY11 Modification Order Value	\$111,894,698
FY11 New Task Order Value	\$338,196,557
FY11 Amount Awarded to Date:	\$450,091,254

Domain - Task Orders

Award Volume

ALA - 63	} Award Value	\$121,430,457
BA - 45		\$42,196,467
ES - 56		\$124,190,290
SE - 37		\$50,379,343
Total TO's for FY11:		201
Avg. Percent of Competition: average of 4 per Task Order		49%
Avg. Days in Queue:		29

FY11 Weighted Avg. Hourly Rate: \$98.29

ALA -\$90.50
BA -\$106.18
ES -\$95.57
SE -\$102.20

FY11 SB Prime Award Volume: \$5,754,146
Single Bids 2% (4 of 201)



2012 Open Season



FY2012 Domain Offerings

- **25 prime vendor position are open in 2012 in all domains**

Domain	Expiring BPA	Lg Prime Openings	Sm Prime Openings	Total Openings	Domain Totals
ALA	3	4	1	5	11
ES	6	7	2	9	13
BA	2	3	3	6	10
SE	2	2	3	5	12

- **NECO/FEDBIZOPPS RFI posted:**

https://www.fbo.gov/index?s=opportunity&mode=form&id=d2cd9b992e9cdb8cb4799b2dd4265462&tab=core&_cview=0



2011-2012 Open Season Schedule



Action	New Vendors	Existing Vendors
NECO Announcement	14-Nov-11	
Open Season Workshop	13-Dec-11	
Open RFQ to Vendors	25-Jan-12	
ES RFQ Released/Proposals Due	25-Jan-12	23-Feb-12
BA RFQ Released/Proposals Due	8-Feb-12	12-Mar-12
ALA RFQ Released/Proposals Due	22-Feb-12	21-Mar-12
SE RFQ Released/Proposals Due	29-Feb-12	30-Mar-12
BPA Modifications executed		30-Jun-12
New BPAs Awarded	1-Jun-12	
New Vendor Orientation	20-Jun-12	
FY12-13 Season Begins	1 June 12/Original Renewal Date	



ACSS WEBSITE

Questions?



Col Peter C. Reddy USMC

Director, Product Group 11



Product Group 11

MAGTF C2, Weapons and Sensors
Development and Integration

MC2I

Marine Corps Systems Command

Marine Corps Systems Command

Small Business Conference

**MAGTF C2, Weapons and
Sensors Development and
Integration (MC2I)**

PG 11 Portfolio Overview

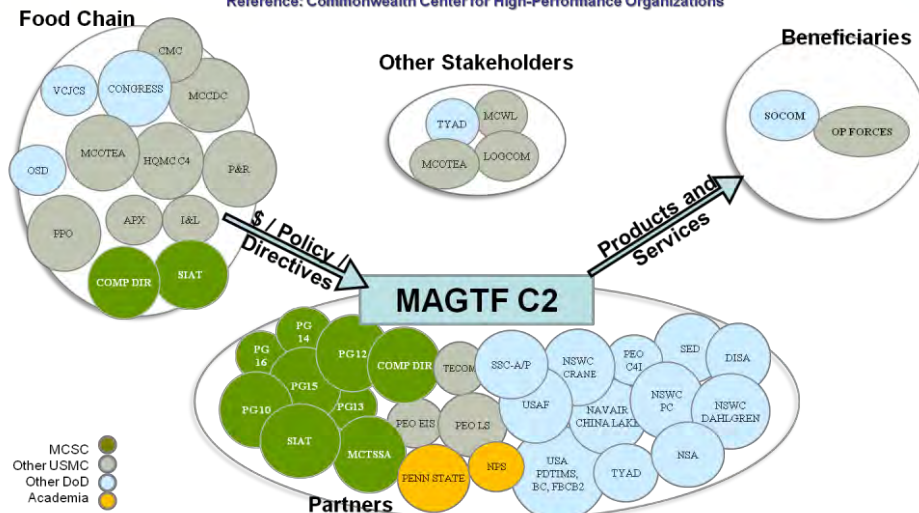
14 December 2011

MISSION

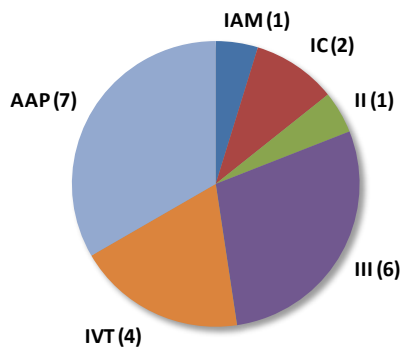
We Acquire, Integrate and Sustain Sensors, Command and Control, and Air Defense Weapons Systems to Enable the Marine Air-Ground Task Force to Accomplish Its Mission

Strategic Stakeholder Value Analysis

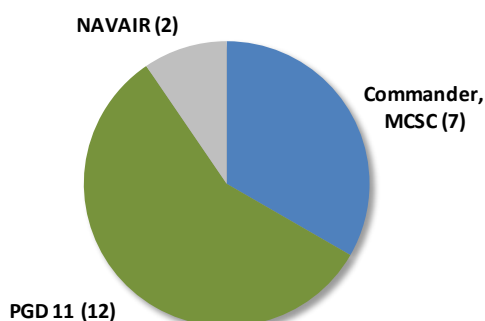
Reference: Commonwealth Center for High-Performance Organizations



Program ACAT Designations



USMC Decision Authority



**21 Designated Programs
69 Total Projects**

Recent Accomplishments

- AN/TPS-59A(V)3 Fielding Decision
- Provided ISR Services for OEF
- Video Scout-MC/2 upgrade fielded to OEF
- CTN Fielding Decision; first units fielded to MACS-2
- Support to deployed AN/TPS-59(V)3 in OEF since 1Q FY 10
- Transfer of TPS-63 from PG 09 to PG 11
- Target Processing Set (TPS) Fielding Decision
- GBAD OTM Technology Initiative Funded by ONR
- M2C2 Units 2 and 3 Fielded to OEF
- Group 3 / STUAS Development Contract Awarded
- Provided in-theater Raven-B training
- MRQ-12(v)4 CIS Fielded



Air Defense Wpns Systems/US: LtCol Ben Stinson

- CTN (III)
- MACCS
- GBAD-T
- Unmanned Systems

Digital Fires and Situational Awareness: Maj Brian Newbold

- AFATDS
- TLDHS
- JBC-P FoS
- BFT FoS
- JBC-P

MAGTF C2 Systems: LtCol Ty Ferrel (Acting)

- COC
- MC2SA
- GCCS/TCO

Radar Systems: Mr. Reginald Brown

- Long Range Radar
 - AN/TPS-59
 - AN/TPS-63
 - 3DELRR
- FTAS
 - AN/TPQ-46
 - LCMR
 - TPS

Technology Initiatives

- Broadband Meshing Data Link (BMDL)
- Secure Comm Console
- DBMA / BMS-MC
- SIE / Disrupt Tolerant Ntwrk
- Corporal JCTD*
- Battlefield Sensor Netting
- TEDS JCTD
- VSCP
- H2C2
- M2C2 / COBRA3



MAGTF C2 Vision:

Marine Air-Ground Task Force Command and Control (MAGTF C2) enhances lethality and effectiveness across the range of military operations through better decision making and shared understanding.

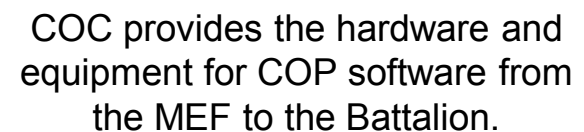
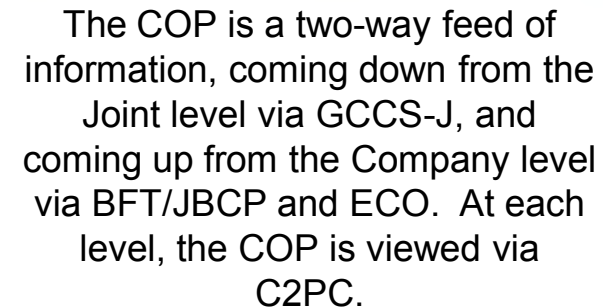
Complex C2/Sensor/Weapons Programs

- Multiple Program, Technical, and Organizational Interdependencies
- Significant Integration Effort
- Interoperability and Information Assurance Certification Required for ~80% of PG-11 Programs
- Software Intensive
 - Significant Maintenance Effort

Joint/Other Service Programs

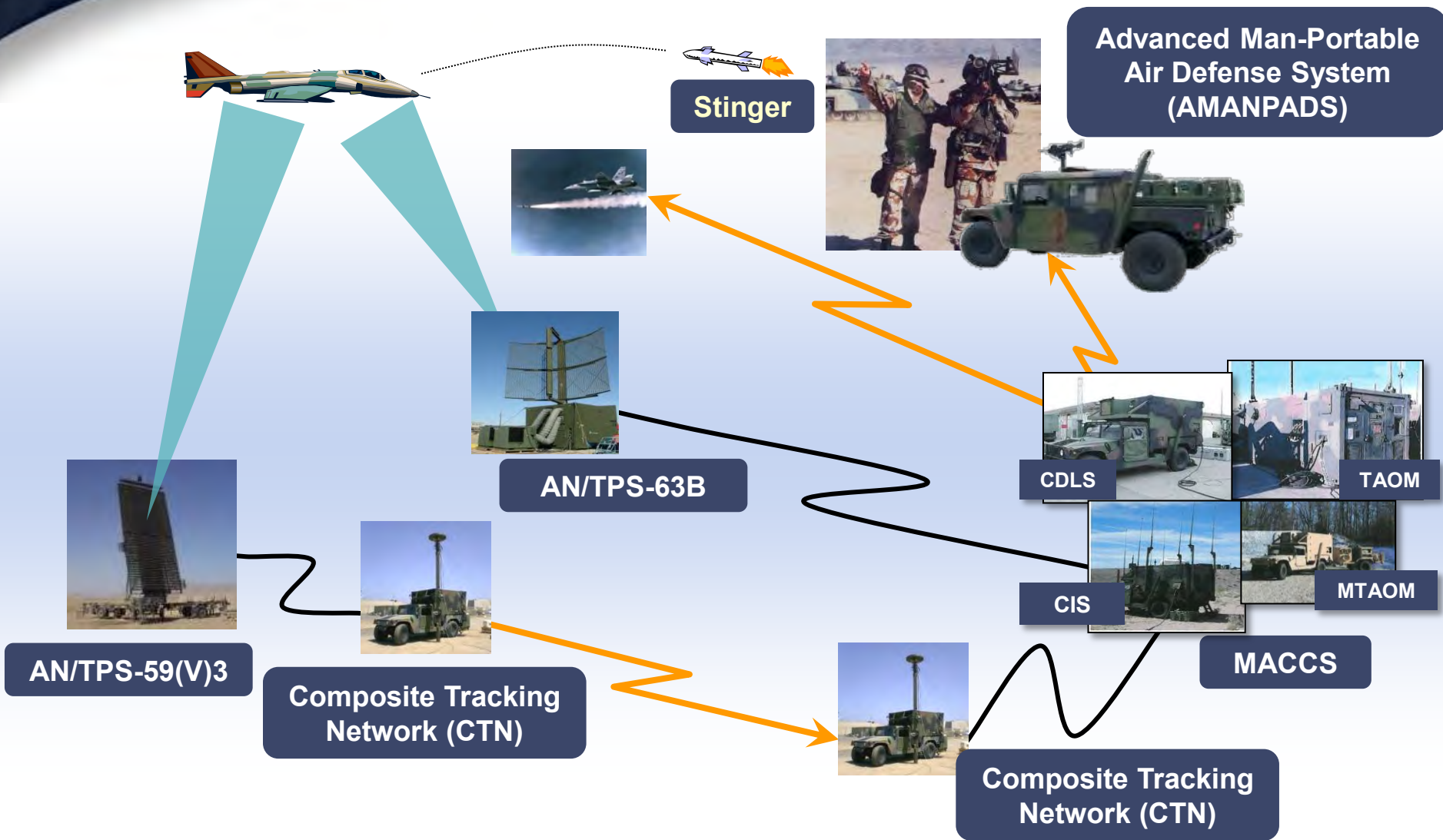
- ~50% of PG-11 Programs
- Significant Interaction and Partnering







Representative Air Defense Engagement String





Representative Ground Fires Engagement String

Raven B Small Unit Remote Scouting System



CDLS



TAOM



CIS



MTAOM

MACCS FoS
• TBMCS
• JTCW

TLDHS / VideoScout



AN/TPQ-48



AN/TPQ-46A

Blue Force Tracker (BFT)



Ground C2 Node
• COC • AFATDS
• TPS • JTCW

UNCLASSIFIED



- **Net-centricity, Service-Oriented Environment and Transition to JC2**
- **USMC / USA JROC-directed C2/SA Convergence**
- **Combat ID**
- **Integrating New C2 Technologies to Improve Existing Capabilities**
- **Footprint Reduction / Lighten the MAGTF**
 - **Handheld C2 Capabilities**
- **Green Initiatives**
- **Sustaining Today's Systems Until Tomorrow's Systems Arrive**
- **Reducing Time to Fuse Multi-level Data at and from the Aviation Combat Element (ACE), Ground Combat Element (GCE), Command Element (CE), and Logistics Combat Element (LCE)**



Questions ?



3DELRR	Three Dimensional Expeditionary Long Range Radar	JTCW	Joint Tactical Common Operating Picture Workstation
ADCP	Air Defense Communications Platform	LAAD	Low Altitude Air Defense
ADWS/US	Air Defense Weapons Systems/Unmanned Systems	LCMR	Lightweight Counter Mortar Radar
AFATDS	Advanced Field Artillery Tactical Data System	M2C2	Mobile Modular Command and Control
AMANPADS	Advanced Man-Portable Air Defense Systems	MACCS	Marine Air Command & Control System
AN/TPS	Army/Navy/Transportable Radar Surveillance	MACCS-S	Marine Air Command & Control System Sustainment
AN/TPQ	Army/Navy/Transportable Radar Special Purpose	MAGTF C2 SA	MAGTF C2 Systems and Applications
BFSA	Blue Force Situational Awareness	MC2I	MAGTF Command and Control Weapons & Sensors Development & Integration
BFT/MTX	Blue Force Tracker/Miniature Transmitter	MC2S	MAGTF Command and Control Systems
BLOS	Beyond Line of Sight	MC2SA	MAGTF C2 Systems and Applications
BUCS	Back-Up Computer System	M-DACT	Mobile Data Automated Communications Terminal
C2CE SW	Command & Control Compact Edition Software	MRC	Mounted Refresh Computer
C2PC	Command & Control Personal Computer	MTAOM	Mobile Tactical Air Operations Module
CDLS	Common Data Link System	MTS	Mobile Tactical Shelter
CID/BTID	Combat ID Device/Battlefield Target ID Device	MUAV	Micro Unmanned Aircraft Vehicle
CIS	Communications Interface System	PG	Product Group
COC	Combat Operations Center	PGD	Product Group Director
COC OTM	COC On The Move	PM	Program Manager
CS	Capability Set	PPM	Post Production Modernization
CTN	Composite Tracking Network	RS	Radar Systems
DACT	Data Automated Communications Terminal	RVVT	Remote Video Viewing Terminal
D-DACT	Dismounted Data Automated Communications Terminal	SAAWF	Sector Anti-Air Warfare Facility
DASC-AS	Direct Air Support Center-Airborne System	SOI/SOA	Service Oriented Infrastructure/Service Oriented Architecture
FOS	Family of Systems	STUAS	Small Tactical Unmanned Aircraft System
FMS	Foreign Military Sales	SURSS	Small Unit Remote Scouting System
FTAS	Family of Target Acquisition Systems	TACC	Tactical Air Command Central
GBAD-T	Ground Based Air Defense Transformation	TAOC	Tactical Air Operations Center
GCCS	Global Command and Control System	TAOM	Tactical Air Operations Module
ISR	Intelligence Surveillance Reconnaissance	TCO	Tactical Combat Operations
JBC-P	Joint Battle Command Platform	TEDS	Tactical Edge Data Solutions
JC2	Joint Command and Control	TLDHS	Target, Location Designation Hand-off System
JCIMS	Joint Combat Identification Marking System	TPS	Target Processing Set
JCR	Joint Capability Release	UUNS	Urgent Universal Needs Statement
JCTI-G	Joint Cooperative Target Identification - Ground	UAS	Unmanned Aircraft Systems
JSS	Joint Interface Control Officer Support System		



PEO Land Systems*

PEO Land Systems

PM Advanced Amphibious Assault (AAA)
 PM Common Aviation Command & Control System (CAC2S)
 PM Ground/Air Task Oriented Radar (G/ATOR)
 PM Joint Light Tactical Vehicle (JLTV)
 PM JPMO, Lightweight 155, Picatinny, NJ (LW 155)
 PM Logistics Vehicle System Replacement (LVSF)
 PM Medium Tactical Vehicle Replacement (MTVR)

COMMANDER

Chief of Staff

Operations Cell
 Postal
 Reserve Affairs
 Security

Chief Management Office (CMO)

Facilities, Services and Supply (FS&S)
 Office of the Command Information Officer (CIO)
 Strategic Change Management Center (SCMC)

Sergeant Major

EXECUTIVE DIRECTOR*

Special Staff

Corporate Communications
 International Programs (IP)
 Office of the Counsel >
 Office of Small Business Programs (OSBP) Safety <

Deputy Commander Resource Management *^

Resource Mgmt
 Competency Domain/
 Competency Leaders

Director,
 Financial
 Management

Director,
 Workforce Management
 and Development

Deputy Commander SIAT *^

Research & Systems
 Engineering
 Competency Domain/
 Competency Leaders

Director,
 Architecture & Cyber
 Engineering

Director,
 Energy & CIED
 Systems

Director,
 Systems Engineering
 and Integration

Director,
 Technology, Test and
 Specialties

Commanding Officer
 MCTSSA
 Camp Pendleton, CA

Product Group 10 Director,
 Information Systems &
 Infrastructure

Product Group 11 Director,
 MAGTF C2, Weapons &
 Sensors Development & Integration

Product Group 12 Director,
 Communications, Intelligence,
 & Networking Systems

Product Group 13 Director,
 Infantry Weapons Systems

Product Group 14 Director,
 Armor & Fire Support Systems

Product Group 15 Director,
 Ground Transportation
 & Engineer Systems

Product Group 16 Director,
 Combat Equipment and
 Support Systems

Program Manager,
 Ammunition

Program Manager,
 Global Combat Support
 System-Marine Corps

Program Manager,
 Light Armored Vehicle
 Warren, MI

Program Manager,
 Mine Resistant
 Ambush Protected

Program Manager,
 Robotic Systems
 Warren, MI

Program Manager,
 Training Systems
 Orlando, FL

Deputy JPEO,
 Chemical & Biological
 Defense
 Arlington, VA

Assistant Commander
 Contracts ^

Contracts
 Competency Domain/
 Competency Leaders

Assistant Commander
 Life Cycle Logistics ^

Life Cycle Logistics
 Competency Domain/
 Competency Leaders

Assistant Commander
 Product Support

Assistant Commander
 Programs ^

Program Mgmt
 Competency Domain/
 Competency Leaders

* = SES Position
 ^ = Competency Director
 > = Counsel reports to Dep Counsel to
 Commandant
 < = Safety reports to SIAT



MARINE CORPS SYSTEMS COMMAND

PROGRAM EXECUTIVE OFFICER LAND SYSTEMS

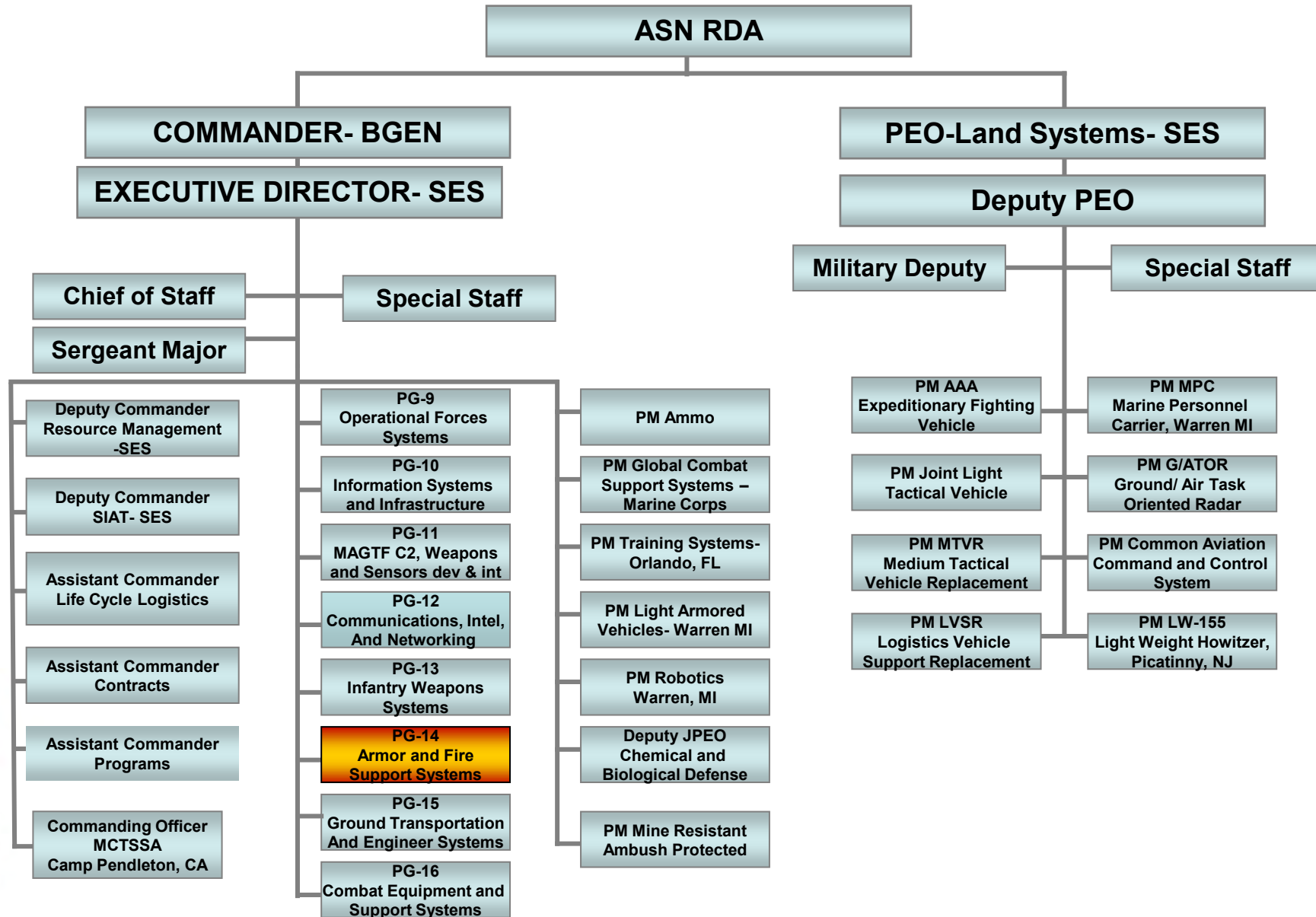


Armor and Fire Support Systems

Product Group 14

Small Business Conference
14 December 2011

Marine Corps Systems Command & PEO Land Systems Organization



Mission & Portfolio

AFSS acquires and sustains assigned armored combat systems, fire support systems, and other related capabilities for the Operating Forces to accomplish their warfighting mission.

Fire Support Systems

- High Mobility Artillery Rocket System (HIMARS)
- Expeditionary Fire Support Systems (EFSS)
- Target Acquisition Devices
- Survey and Meteorological Systems

Tank Systems

- M1A1 ABRAMS Tank
- M88A2 Recovery Vehicle
- Armored Vehicle Launch Bridge (AVLB)



Current Focus

- Not necessarily building new Armor and Fire Support systems, we're sustaining and improving already fielded equipment.
- Whether it's through new innovative logistics or maintenance process, or by adding capability to currently fielded systems, we are always looking for ways to improve our equipment and the services that we provide to our Marines.



Product Group Principals

Director, **Colonel Joe Shrader**

PM Fire Support Systems, **Mr. Keith Davis**

PM Tank Systems, **LtCol John (Ethan) Smith**

Competency Team Alignment

- Business Manager: **Vacant**
- Contracts Manager: **Mr. Edwin Wright**
- Lead Financial Manager: **Mr. Jeffrey Speer**
- Lead Engineer: **Mr. Craig Melton**
- Lead Logistician: **Mr. Jeffry Gibbs**





MARINE CORPS SYSTEMS COMMAND

PROGRAM EXECUTIVE OFFICER LAND SYSTEMS

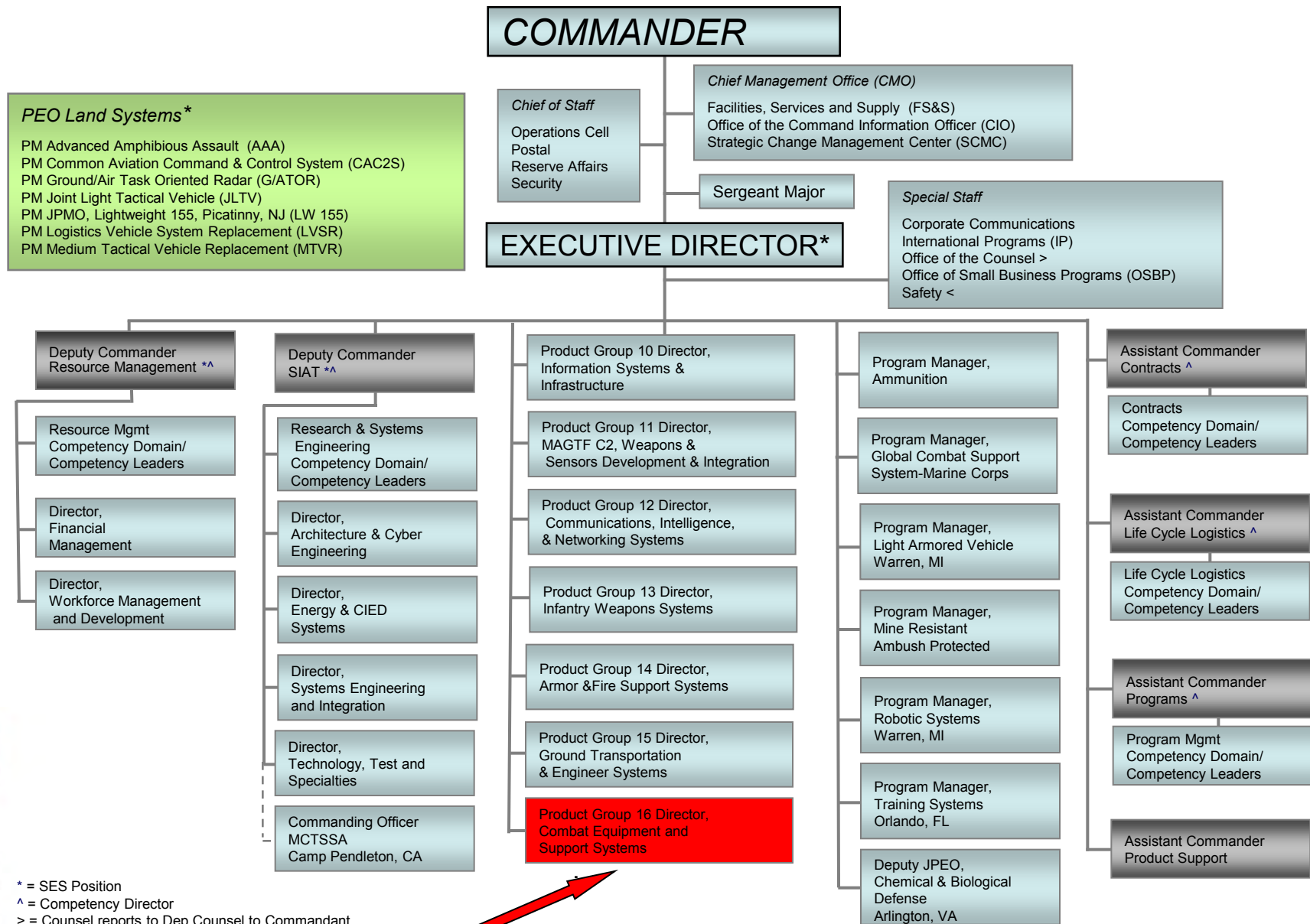


Combat Equipment and Support Systems

Product Group 16

Small Business Conference
14 December 2011

MARCORSYSCOM ORGANIZATION



* = SES Position

^ = Competency Director

> = Counsel reports to Dep Counsel to Commandant

< = Safety reports to SIAT



Mission & Portfolio

We are the Life Cycle Managers for:

- Test, Measurement, Calibration, and Diagnostic Equipment
- Personal Protective Equipment
- Uniforms and Uniform Items
- Cold Weather Gear
- Chemical, Biological, Radiological, and Nuclear Defense Equipment
- Field Medical Equipment
- Food Service Equipment
- Shelters and select associated equipment (heaters)
- Autonomic Logistics
- IED Detection Dogs



Current Focus

- **Lighten the individual Marine's load and improve his personal protection**
 - Enhanced Combat Helmet
 - Multifunctional clothing and equipment
 - CBRN protection and detection
- **Reduce our expeditionary life support logistic demands**
 - More durable, efficient soft-wall shelters
- **Increase our Weapon Systems' and Ground Combat and Logistic Vehicles' Operational Availability**
 - Autonomic Logistics
 - Modular, Portable, Battery Powered, Multifunctional Test Equipment
 - Longer calibration cycles
- **Enhance our field medical equipment capabilities**
 - Level I and II equipment



Product Group Principals

DPGD: *Mr. Todd Wagenhorst*

PM Combat Support Equipment: *Mr. Scott Adams*

PM Infantry Combat Equipment: *LtCol Kevin Reilly*

PM Test Measurement Diagnostic Equipment: *Mr. Dean Johnson*

PM IED Detection Dogs: *LtCol Kenneth Burger*

MCUB Lead: *Mrs. Mary Shapleigh*

Competency Alignment Team

Business Manager: *Mr. Neil Justis*

Contracts Manager: *Mrs. Dorinne Rivoal*

Lead Financial Manager: *Mrs. Carolyn Reynolds*

Lead Engineer: *Mr. Nicholas Sifer*

Lead Logistician: *Mrs. Rega Reid*

Instruction Systems Specialist: *Mrs. Katie Bryan*



Questions?





Brief to Small Business



Jim Smerchansky

Deputy Commander

Systems Engineering, Interoperability, Architecture & Technology

Marine Corps Systems Command



35TH COMMANDANT OF THE MARINE CORPS
COMMANDANT'S PLANNING GUIDANCE

2010

- *We will continue to provide the best trained and equipped Marine units to Afghanistan. This will not change. This remains our top priority!*
- *We will rebalance our Corps, posture it for the future and aggressively experiment with and implement new capabilities and organizations.*
- *We will better educate and train our Marines to succeed in distributed operations and increasingly complex environments.*
- *We will keep faith with our Marines, our Sailors and our families.*

The objective is to allow Marines to travel lighter, with less, and move faster through the reduction in size and amount of equipment and the dependence on bulk supplies. - Gen Amos, 35th Commandant's Planning Guidance



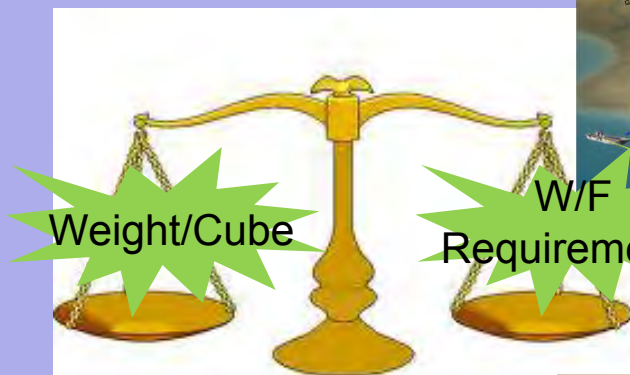
OPPORTUNITIES

- Reduce Weight
- Reduce Energy
- Reduce Cost

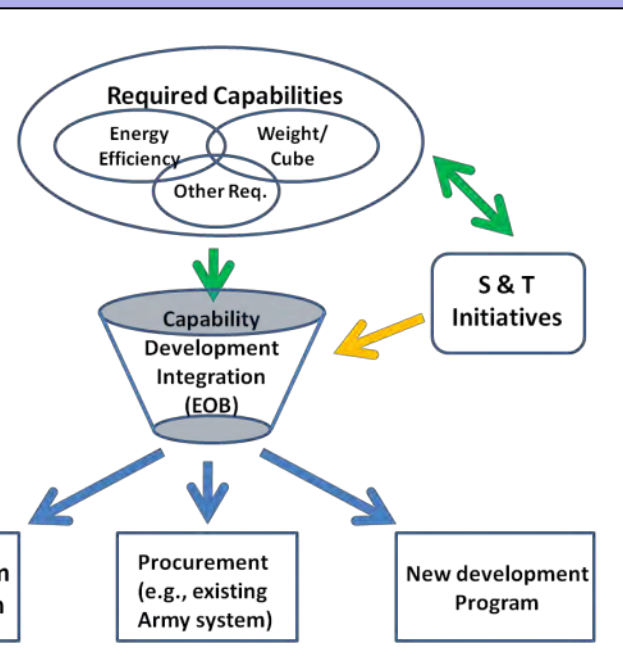
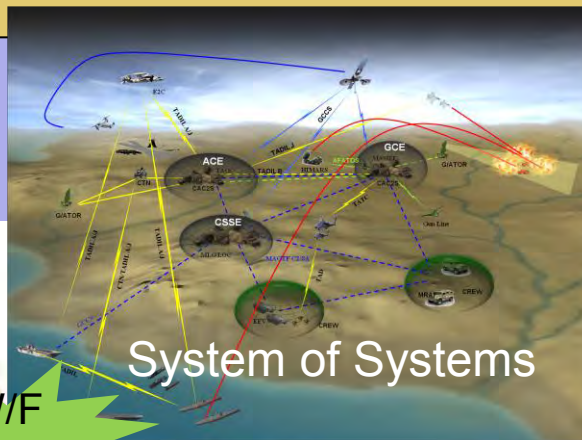


“We will rebalance our Corps, posture it for the future and aggressively experiment with and implement new capabilities and organizations.”

The Challenge



Affordability /
Technology



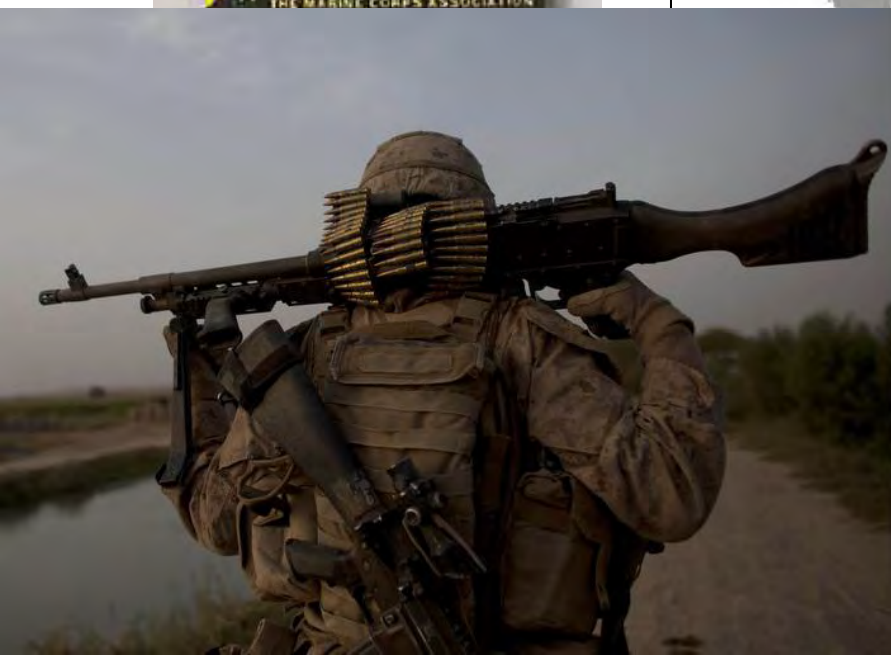
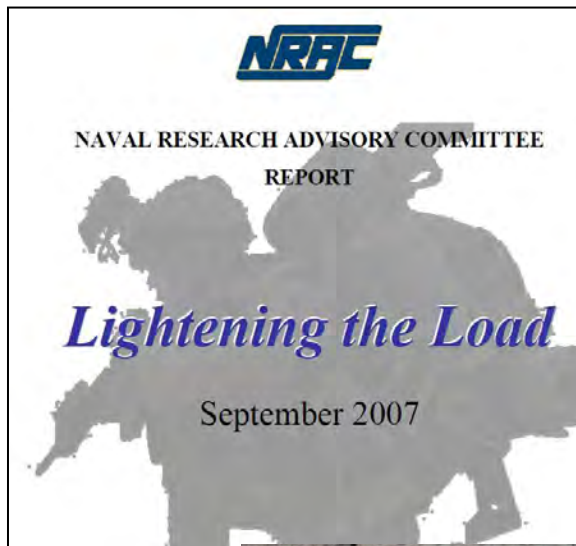
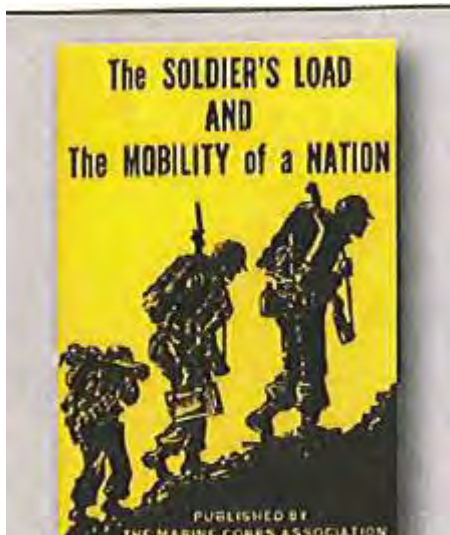
Capability Solutions

Create the Middleweight MAGTF
within Affordability Constraints

MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Combat Weight
of Marines



MARINE CORPS SYSTEMS COMMAND

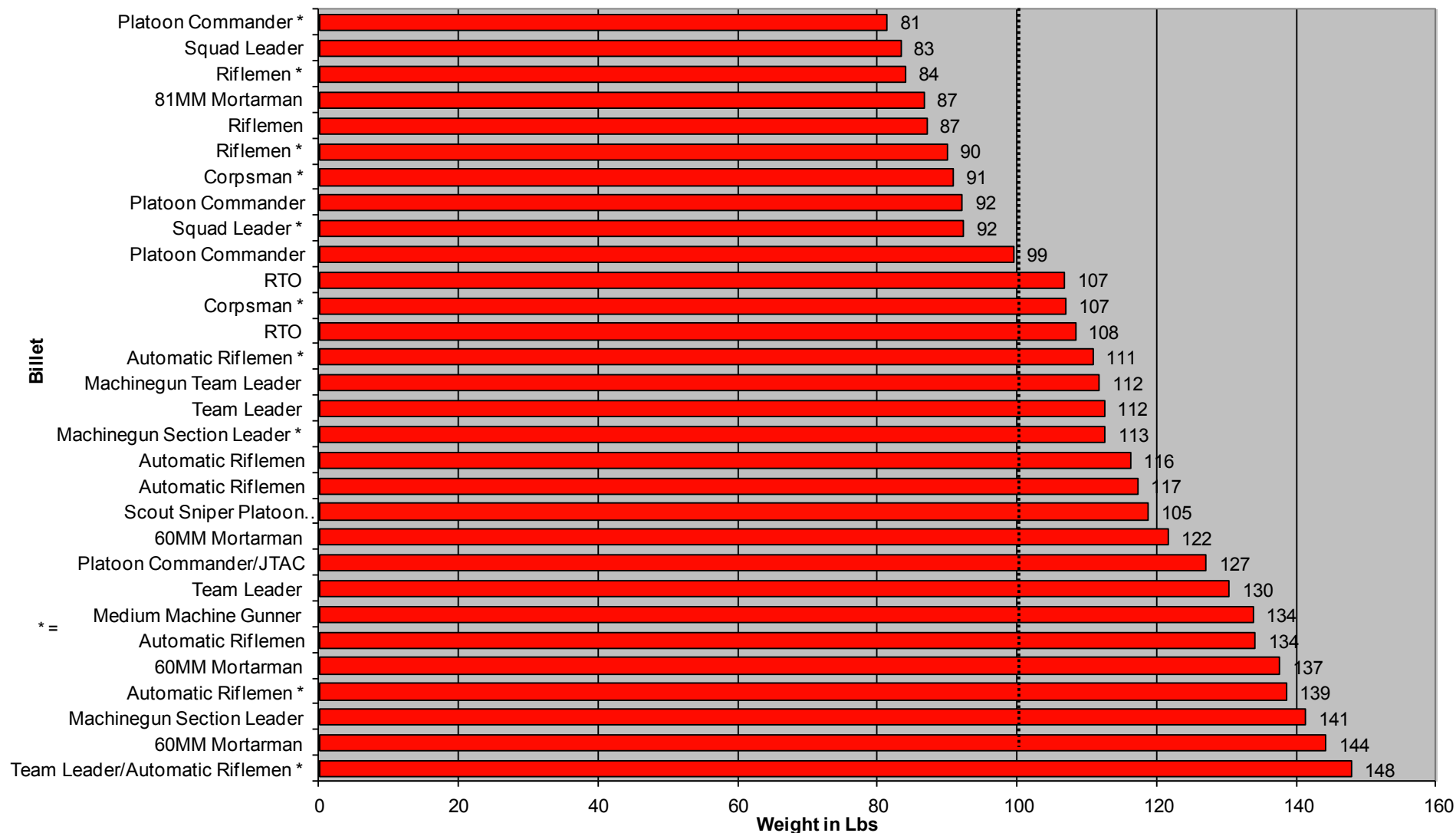
EQUIPPING THE WARFIGHTER TO WIN

2nd Bn
7th Marines



2/7 April 2008 Equipment Weight by Billet

Average Weight 112 lbs



MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

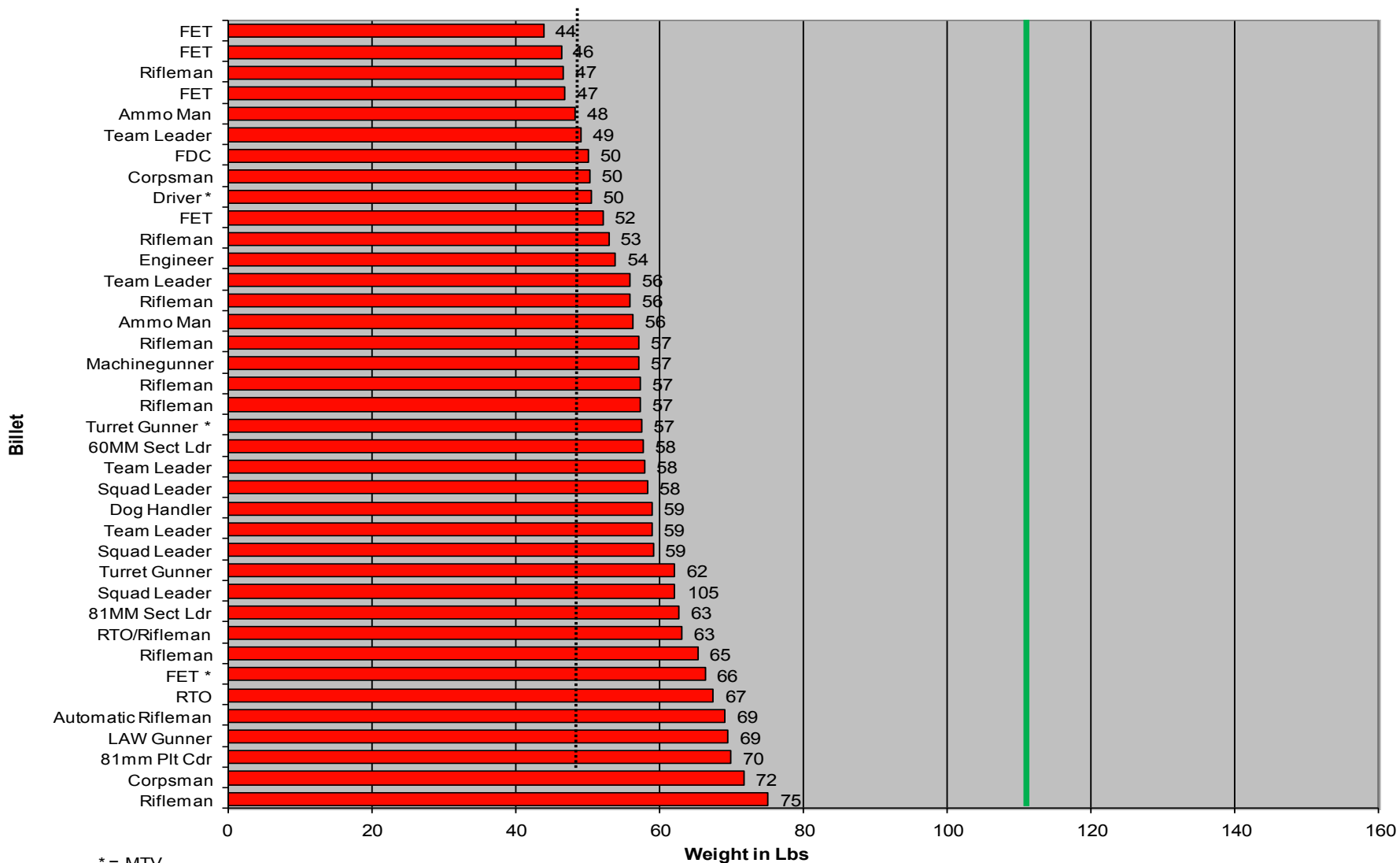
2nd Bn
2nd Marines

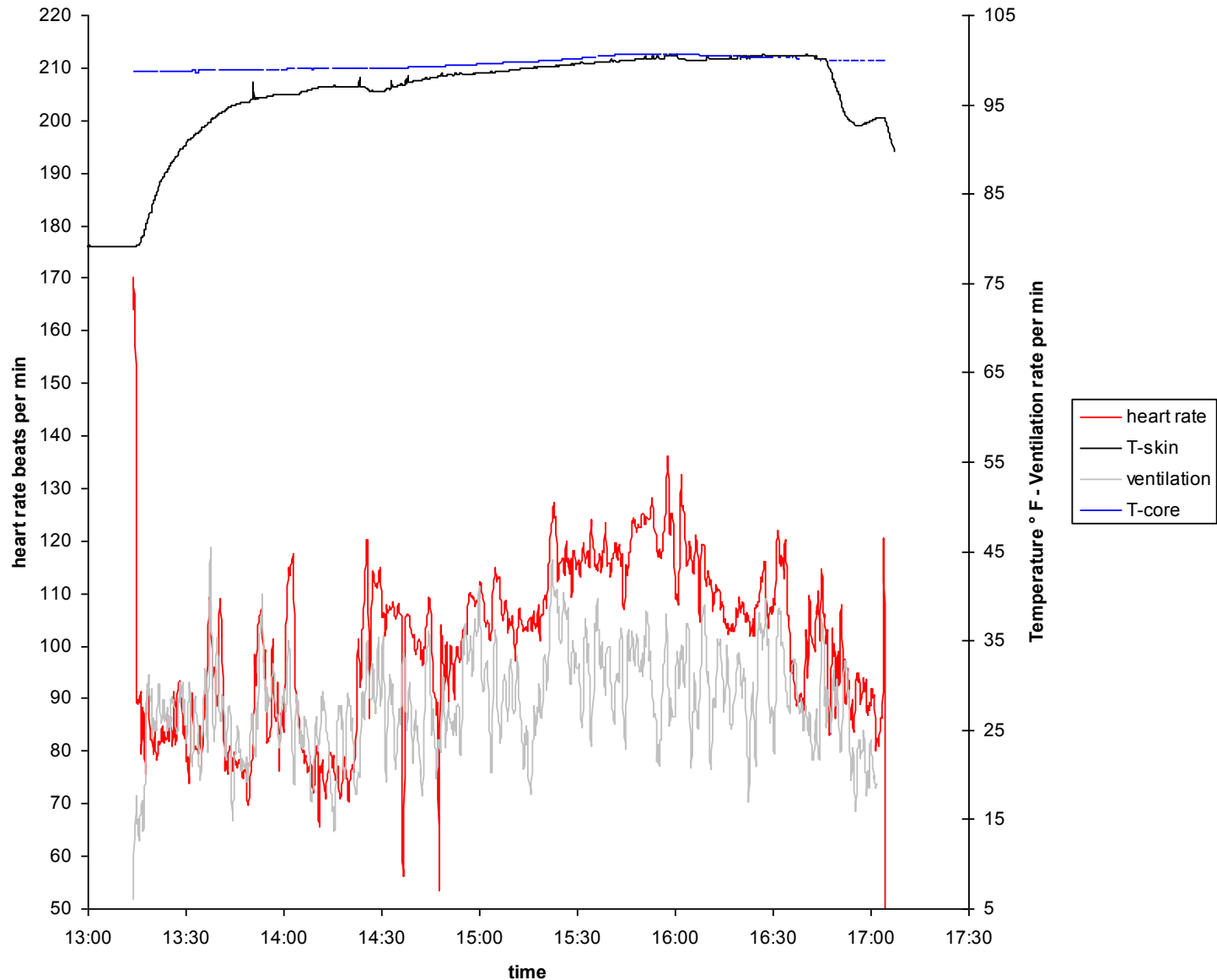


2/2 March 2010 Equipment Weight by Billet

Average Equipment

2/7 Avg Equipment Weight
112 lbs





MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Thermal Heat Strain



1st Lt. Thomas "Tee" Tompkins with Company E, 2nd Battalion, 8th Marine Regiment, scans a possible enemy position with his rifle combat optic Aug. 10, 2009.



Pfc. Janos V. Lutz, machine gunner, Company E, 2nd Battalion, 8th Marine Regiment, races down his squad's position to get more ammo while receiving fire from enemy positions, Sept 2009.

MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Energy Efficiency





CURRENT

Fuel Used	Generator	ECU	Shelter
1.22 gal/hr 14 kW load	15 kW MEP-804A TQG	96,000 BTU/hr B0010 model	R-2 Insulation Base X 305

FUTURE

Fuel Used	Generator	ECU	Shelter
0.52 gal/hr 9.3 kW load	10 kW MEP-1030 AMMPS	60,000 BTU/hr ECU 2014 model	R-4 Insulation Base X 305 w/ Liner

**57% Reduction in
Fuel Demand**

25% Efficiency gain
in Power Generation

15% Reduction in
Power Demand

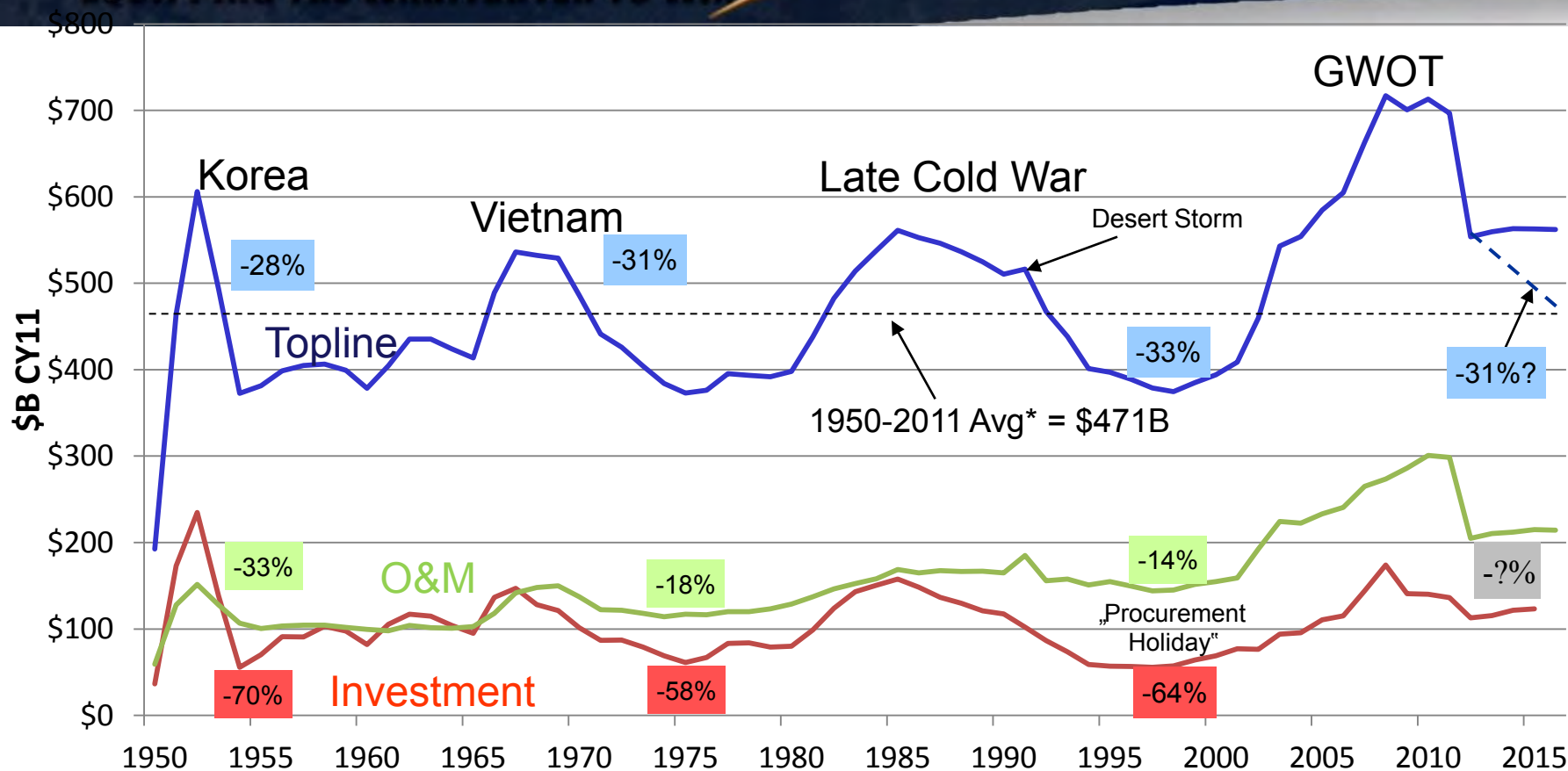
33% Reduction in
Cooling Demand

MARINE CORPS SYSTEMS COMMAND

EQUIPPING THE WARFIGHTER TO WIN

Energy and Small Business





- Recent top line drawdowns average ~30%
- Procurement (Investment) accounts take disproportionate hits, e.g., 14% (O&M) vs. 64% (Investment) in post Cold War era



Cost to Equip Individual Marine

After accounting for inflation the cost today is **6.4 times the cost** of equipping an individual Marine in 2000.

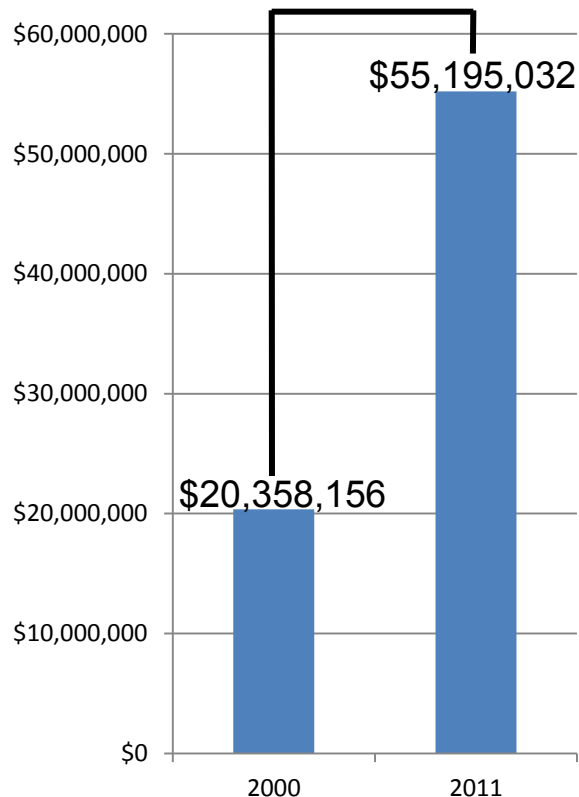
CY 2011 Dollars

Year 2000	Year 2010
	
Basic Rifleman's Clothing & Equipment Cost	
~\$2,346	~\$12,731

Cost to Equip Inf. Bn

After accounting for inflation the cost today is **2.7 times the cost** of equipping an Inf. Bn. in 2000.

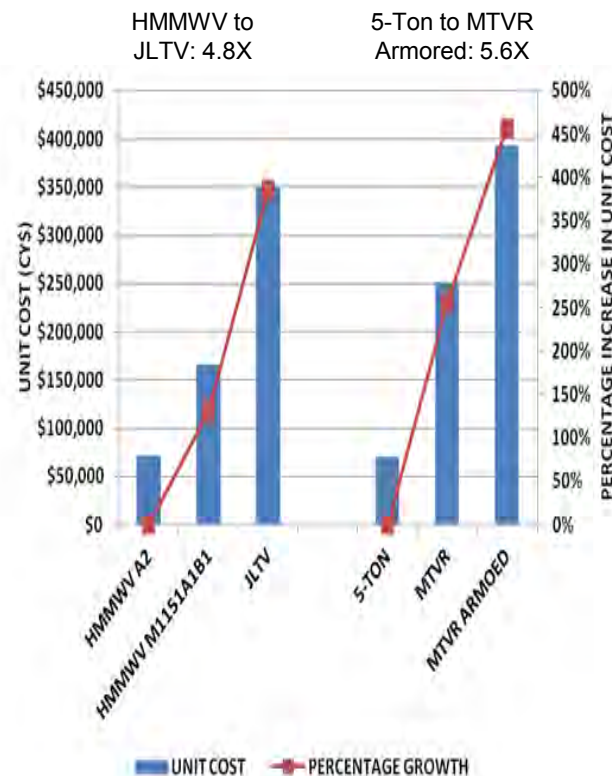
CY 2011 Dollars

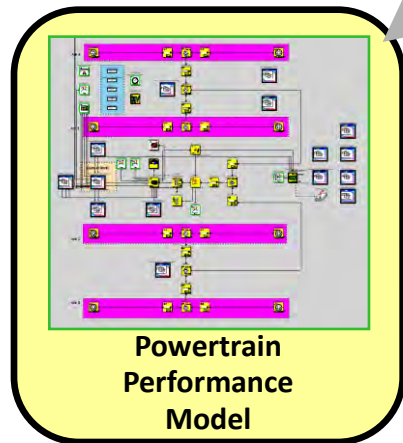


Cost of Combat and Tactical Vehicles

After accounting for inflation the cost today is **5.2 times the cost** of acquiring combat/tact vehicles in 2000.

CY 2011 Dollars

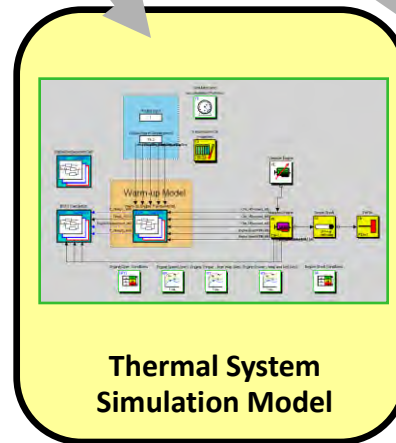




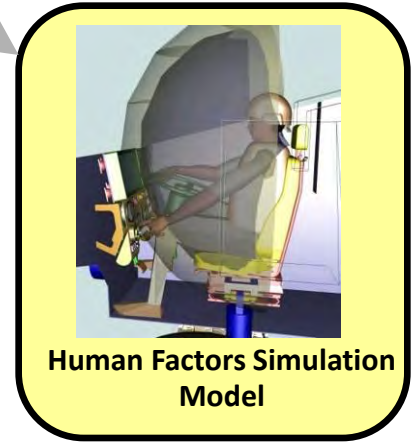
Powertrain
Performance
Model



Mobility Simulation Model



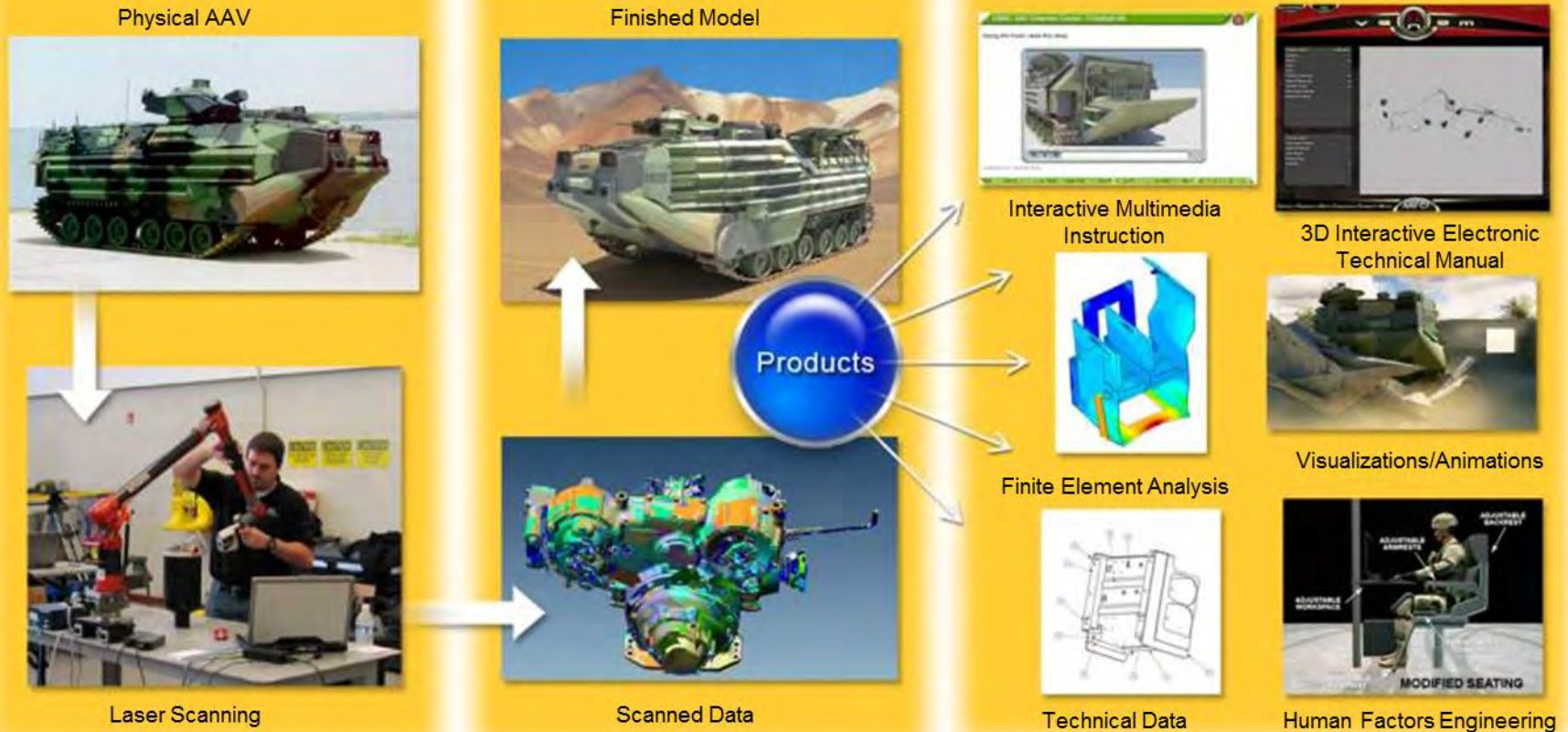
Thermal System
Simulation Model



Human Factors Simulation
Model

Understand How Requirements Effect Cost - Optimize Design

Legacy Platform /Service Life Extension Program (SLEP) Capability



Modeling and Simulation based Systems Engineering



MARINE CORPS SYSTEMS COMMAND PROGRAM EXECUTIVE OFFICER LAND SYSTEMS



“Give these guys a mission, some leadership, a little chow, lots of ammunition, and then stand back...”



DON Mentor-Protégé Program



Oreta Stinson
Deputy Director,
Department of the Navy
Office of Small Business Programs

December 14, 2011





What is the DoD Mentor-Protégé Program?



- ❑ Congressional Mandated DoD Program established as Pilot in 1990 under section 831 of Public Law 101-510 to incentivize large businesses (mentors) to provide development assistance to small businesses (protégés) through an approved agreement.
- ❑ Annual funding varies
 - Navy \$5M
- ❑ DoD Military Services and Agencies approve agreements
- ❑ Limited to eligible small business groups (SDBs, 8As, SDVOSBs, HUBZones, WOSB, entity employ 20% severely disabled)
- ❑ Over 1000 small businesses developed
 - Highly regarded by Congress, other Agencies and Industry
- ❑ Active agreements
 - 7 current active agreements





What are the types of Mentor-Protégé Agreements?

- Types of agreements:
 - Reimbursable
 - A reimbursable agreement provides monetary reimbursement only for the cost of developmental assistance incurred by the mentor firm provided to a protégé firm in accordance with the approved agreement. These agreements are managed by Military Services and other Defense Agencies.
 - Credit
 - A credit agreement provides the mentor credit against applicable subcontracting goals established under contracts with DoD and other Federal agencies. These agreements are managed through DCMA.





FY2011 Mentor-Protégé Budget



Navy FY-11 Budget



DoD FY-11 Budget





Technology Requirements/Alignments



- Protégés must align their technology requirement with:
 - Business Infrastructure
 - Certifications
 - Construction
 - Engineering
 - Environmental Remediation
 - Green Technology
 - Guam Build-up
 - Manufacturing
 - Research and Development
 - UAV Technology Development





Mentors Requirements

- ❑ Prior to participation, mentor firms must complete and submit a mentor application to the Office of the Secretary of the Defense (OSN), Small Business Program Director, for approval as a mentor firm under the program (DFARS Appendix I-105).
- ❑ The Application may be submitted concurrently with the proposed Mentor-Protégé agreement.
- ❑ A mentor may have several Mentor-Protégé relationships; However, a protégé may have only one mentor at any given time.
- ❑ A separate Mentor-Protégé agreement must be submitted for each Mentor-Protégé relationship.





Benefits to Mentors

Incentives for large businesses to participate in this program:

- Assist small businesses in enhancing their capabilities and to increase participation.
- Compensation for costs associated with Mentor-Protégé agreements.
- Develop long-term relationships with qualified small business vendors.
- Teaming opportunities with the Protégé to win new contracts and/or subcontracts.





Protégés Eligibility

- ❑ Must be eligible to participate as a protégé firm:
 - Small Disadvantaged Business (SDB)
 - ❑ Indian Tribe
 - ❑ Native Hawaiian
 - ❑ Native Alaskan
 - Woman-Owned Small Business (WOSB)
 - Service-Disabled Veteran-Owned Small Business (SDVOSB)
 - HubZone
 - Entity employing at least 20% severely disabled





Benefits to Protégés

The incentives for small businesses to participate in this Program:

- Open doors
- Use as a marketing tool
- Pursue business with other prime contractors
- Receive assistance from a major prime contractor
- Develop long-standing business relationship May receive non-competitive subcontracts under cost-type contracts.
- Teaming opportunities with the mentor to win new contracts and/or subcontracts





Evaluation Process

- Evaluation Process:
 - All proposals shall be submitted to Head Contracting Agency (HCA) Small Business Office.
 - Two months prior to DON OSB submission cycle for processing
 - The mentor is required to obtain sponsorship of the agreement from the cognizant program office after coordination with the cognizant Small Business Office





Evaluation Process

- All proposals shall be submitted to and endorsed by a Head Contracting Agency (HCA) Small Business Office.
- The HCA Small Business Office should forward endorsed agreements for evaluation to the Mentor-Protégé Program Manager for final review by close of business on the following cut off dates.
 - ❑ *March 31st*
 - ❑ *July 31st*
 - ❑ *November 30th*





Northrop Grumman Electronic Systems/Customs Manufacturing & Engineering



TPS800

SUPPORTS: GATOR, E/A-18 Power Supply

- CME is a WOSDB- Designs and Manufactures Military and Industrial Electrical Power Products and Unattended or Remote, Ground-based wireless Sensor Networks

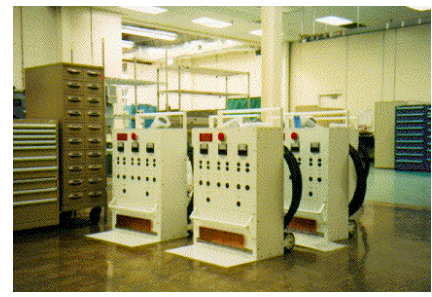
Tactical Power Supplies



Unattended Ground Sensors

BENEFITS

- Enhanced Power Supply Design and Manufacturing Capability
- Improved Proposal Risk Assessment Tool
- State-of-the-Art Enterprise Resource Planning System



Ground Support Equipment
(Aerospace)





Program Reporting

- ❑ Monthly Expenditure Reports
 - Due to OSBP 20th of every month
 - ❑ Monthly expenditure reports are required to be submitted to the cognizant Small Business Office on a quarterly basis. Inaccurate and late reports will have a negative impact on the decision for approval of your priced option.

- ❑ Semi-Annual Reports
 - Mentor submits semi-annual reports to DCMA
 - ❑ Extra emphasis is placed on the semi-annual reports that are required under this program. These reports are reviewed and are a major part of the decision-making process to determine if incremental funding will be approved. Inaccurate and late reports will have a negative impact on the decision for approval of your priced option.





Program Reviews

- ❑ Semi- annual Program Management Reviews (PRMs)
 - @ DoD Mentor-Protégé Conference
 - August of each year

- ❑ Incremental Funding Reviews
 - Conducted 30 days prior to funding requirements (option years)
 - 90% of current period agreement milestone (annually)
 - 75% of distributed funds expended

- ❑ DCMA Post Program Reviews
 - Conducted 2 fiscal years after expiration of the agreement





DON Nunn Perry Award Winners

Where are they now?



Awardees Sponsor	Mentor	Protégé	Business Type	Location	Status	Goods/Services
2011 (FAC)	SAIC	ERRG	WOSB	CA	Large	Environmental Remediation Services
2010 (AIR)	Lockheed Martin	Aegisound	HUBZone	VA	Small	Advanced Hearing Protection Supplier
2009 (SUP)	Q.E.D.	MIS	SDVOSB	NC	Small	Plate and Sheet Metal Work Supplier
2009 (AIR)	Raytheon	Tampa Brass & Aluminum	SDVOSB	FL	Small	Aluminum Foundries
2007 (AIR)	Raytheon	The Enser Corporation	SDVOSB	FL	Small	Secondary Weapon Battery Supplier
2006 (WAR)	Lockheed Martin	M&M Technical Services	WOSB	VA	Small	Data Processing, Engineering Services
2006 (FAC)	Shaw Environmental	ERRG	WOSB	CA	Large	Environmental Remediation Services
2005 (AIR)	Raytheon	Tampa Brass & Aluminum	SDVOSB	FL	Small	Aluminum Foundries
2003 (AIR)	The Boeing Company	DACA Machine & Tool	WOSB	VA	Small	Fabricated Structural Metal
2002 (FAC)	Foster Wheeler Environmental	Nobis Engineering	SDB 8(a)	NH	Large	Environmental, and geotechnical engineering
2000 (AIR)	The Boeing Company	Manufacturing Technology	SDB 8(a)	FL	Sold	Electronic Manufacturing
1999 (FAC)	IT Group	Innovative Technical Solutions	SDB 8(a)	CA	Large	Environmental and Engineering
1997 (AIR)	Hughes Missiles Systems	Summa Technology	SDB	AL	Large	Hardware Manufacturing



NAVY MENTOR-PROTÉGÉ

PROGRAM MANAGER



Oreta Stinson

Small Business Programs

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The Department of the Navy Office of Small Business Programs



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- Military Sealift Command
- Naval Air Systems Command
- Naval Facilities Engineering Command
- Naval Inventory Control Point
- Naval Sea Systems Command
- Naval Supply Systems Command
- Office of Naval Research
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– in the final analysis
this is what matters
most.





Questions and Answers





UGVs IN THE FIGHT — MAKING A DIFFERENCE

LtCol Dave Thompson, USMC, Project Manager



14 December 2011

Distribution Statement A: Approved for public release; distribution is unlimited.



Mission

Lead the development, systems engineering, integration, acquisition, testing, fielding, sustainment and improvement of unmanned systems for the Joint Warfighter to ensure safe, effective and supportable capabilities are provided while meeting cost, schedule and performance.

Vision

Continuous improvement of unmanned system capabilities to meet current and future Joint Warfighter objectives.



Evolution of Ground Robotics in Combat

- Sustainment, Modernization, Interoperability and Modularity

ROBOTIC SYSTEMS JPO

2004

162 systems

- No single vendor could produce 162
- 5 vendors, multiple configurations
- Joint effort, EOD focused

2005

1800 systems

- Robot's proven ability to save lives
- Expansion beyond EOD mission (Countermines, Security)
- Agreements w/ AMC and REF

2006

4000 systems

- Engineers and Infantry
- Route clearance, Explosive detection & Weaponization development

2007

5000 systems

- Special Forces robot applications assessed
- Route clearance, Explosive detection & Weaponization on battlefield

2008

6000 systems

- Maneuver elements
- Range extension
- CBRNE detection
- Persistent surveillance
- RC HMMWV
- More capable payloads

2009-2010

7000 systems

- Military Police
- Smaller platforms
- Enhanced battery life
- Commonality
- Remote deploy
- More capable payloads

2011-Future

- Interoperability
- 'Plug & play' capabilities
- Limited autonomy
- Weaponization
- Increased agility and dexterity

Almost one third of robots issued to units in 2009-2010 went to units other than EOD and Combat Engineers.

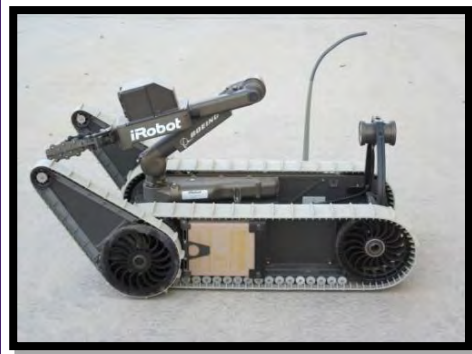
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Robots Currently in Combat

Unclassified

Mini-EOD
(SUGV-310) (~400)



PackBot Family (~1100)



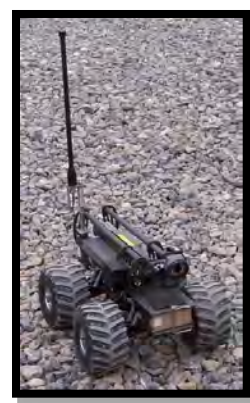
SUGV XM1216
w/Tether (38)



TALON Family (~1000)



MARCBot
(~350)



M160 (45)



ROBOTIC SYSTEMS JPO

Unclassified



Unclassified

Joint Robotics Repair Detachment – Afghanistan



ROBOTIC SYSTEMS JPO



Program Executive
Office Ground Combat
Systems
PEO Mr. Scott Davis

Warren, MI



Marine Corps Systems
Command
BGen Frank L. Kelly
USMC

Quantico, VA



Robotic Systems Joint
Project Office
PM LtCol David Thompson
USMC

Warren, MI



Distribute



Repair



Train

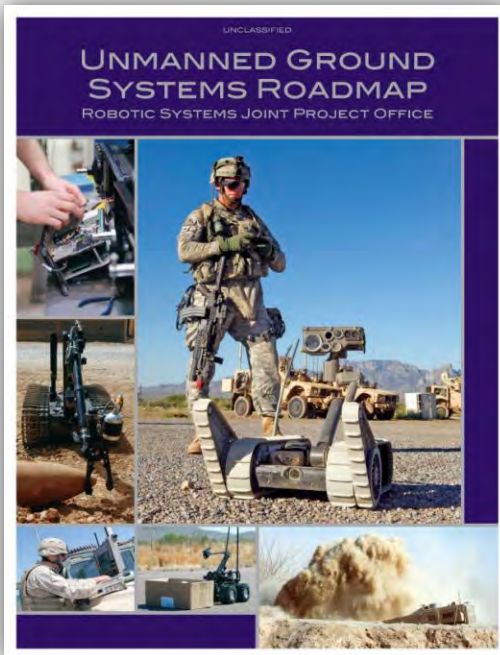




Unmanned Ground Systems Roadmap

July 2011

- RSJPO Organization
- Technology Needs/Enablers
- Modernization Strategy
- Systems/Programs Portfolio
- Technology Needs



		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
		estimated timeline									
Autonomous Navigation	Technology	Adjustable Waypoints	Layered Planning	Object Detection & Tracking				Trust Conscious			
	Capability	Applique Autonomy Kits	Incremental Advancements in Navigation and Sensor Fusion (throughout)				Formation Control/ Multi Robot		Operations in High Latency/ Low Bandwidth Environment		Autonomous Operations
Communications	Technology	Way Point Navigation	Semi-Autonomy	Safe Ops in Urban Environments				Cognitive Radio		Global Mesh Networking	
	Capability	RF Addressable Radio	Mesh Networking/ Repeaters	Smart Antennae/ MIMO				Encryption Standards			
Power	Technology	Software Defined Radio	Multi-Cast				Encryption Standards		Global Mesh Networking		
	Capability	Single Radio Communications	Increased Communication Range				One Operator/Multiple Robot Control		Any Operator / Any Robot Control		
Vision	Technology	Improved Performance: Li-Lan Technologies	100 W Fuel Cell Packaged Fuel	Fuel Cell On Board Processed Bulk Fuels				Advanced Fuel Cell Tech (P8 Reformation on Platform)		Image Search/ Object Identification	
	Capability	Hybrid Energy Storage	Incremental Advancements in Power Management & Energy Harvesting (throughout)				Longer Duration Silent Watch		Increase Service Life, Increased Energy Density		
Architecture	Technology	Improved Duration & Reduced Signature	Incremental Improvements in Power and Energy Performance (throughout)				Stereographic Imaging/Display Tech/ Improved Software		Image Search/ Object Identification		
	Capability	1024 x 768 IR	Stereographic Imaging/Display Tech/ Improved Software				1820 x 1080 IR		Stereoscopic Processing		
SWM	Technology	On-Chip Image Enhancement	Visible IR Fusion				1820 x 1080 IR		Stereoscopic Processing		
	Capability	Increased Range Performance	Increased Awareness in All Light Conditions				Depth Perception / 3D Data Collection		Human-like Visual Cognitive Understanding		
Manipulators	Technology	Open Architecture, Accepted Specification Standards	Government Mandated Common Open Architecture				Industry Provides Open Common Architecture				
	Capability	UGV / UAS Shared Situational Awareness	UGV Common Domain Controller				UGV Cross Domain Controller				
Terrain Mobility	Technology	One Operator/ One Robot Control	Information and Plan Sharing Across All UGVs				Improved Teaming with Domain Collaboration Across Domains		Coordinated Activities Across Multiple Distant US		
	Capability	Mounted Touch Screen Displays	Dismounted Touch Screen Displays				Advancements in Interface Automations & Neuro-Ergonomics				
Payloads	Technology	Tactile Feedback	Voice Recognition				Flexible Displays				
	Capability	OCU w/ Multiple Disparate Robots in One Domain	One Operator / Multiple Disparate Robot Control				Wearable Interfaces		One Operator / Multiple Autonomous Robot Control		
Payloads	Technology	Inverse Kinematics	Visual Servos				Inverse Dynamics		3D World Modeling, Control Algorithms		
	Capability	Gastless Control	Haptic Feedback (bulky handling)				Efficient Arm Movement		Heavy Lifting		
Payloads	Technology	Automatic Tool Change	Terrain Recognition				Waterproof/ Swim/Jump Kit		Object Classification Algorithms		
	Capability	Stability Control & Semi-Active Suspension	Snake-Like Robots				Adaptive Behavior to Terrain		Legged Robots		
Payloads	Technology	Rollover, Overcenter & Understeer Recovery	High Obstacle Negotiation				Non-Lethal/ Lethal Weapon Systems		Brain-Computer Interfaces		
	Capability	Platform/30W Track or 6 Wheeled	Low Cost LIDAR				Fuel Cells/Generators		Offensive Missions		
Payloads	Technology	Visual/IR/Thermal/ Stereo Cameras	UWB Radar				Non-Lethal/ Lethal Weapon Systems		Brain-Computer Interfaces		
	Capability	Limited 3-D World Building	Supervised Autonomy				Persistent Stare		Greatly Increased Control		
Payloads	Technology	Low Cost LIDAR	Fuel Cells/Generators				Offensive Missions		Autonomous Operations		
	Capability	Limited 3-D World Building	Supervised Autonomy				Persistent Stare		Greatly Increased Control		

UGV Emerging Requirements

- **Autonomous Mobility Appliqué System (AMAS)**
 - » Add-on appliqué system to virtually any manned vehicle (Joint)
 - » Requirement Document in staffing
 - » Joint Capability Technology Demonstration approved
- **Squad Multi-Purpose Equipment Transport (SMET)**
 - » Semi-autonomous utility/cargo platform (USA)
 - » Requirement Document in staffing
- **Engineer Squad Robot (ESR)**
 - » Man-portable, lightweight robot (USMC)
 - » Requirement Document Approved
- **Throwable/Ultra Light Recon Robot (ULRR)**
 - » Under 10 lb robot (JIEDDO, USMC, REF)
 - » Requirement Document Approved/Funded
- **Tactical Robot Controller (TRC)**
 - » “Common Controller” (USMC)
 - » Requirement Document in staffing





Way Ahead/Opportunities for Small Business

- Interoperability and Commonality goals
 - Interoperability profiles – industry participation
 - Promotes modularity
 - Promotes competition
 - Reduces logistics burden
- Partnering between Defense and Industry
 - NDIA, AUVSI, Robotic Technology Consortium
- Next Major Contract Actions
 - ESR, ULRR





Any Questions?

ROBOTIC SYSTEMS JPO

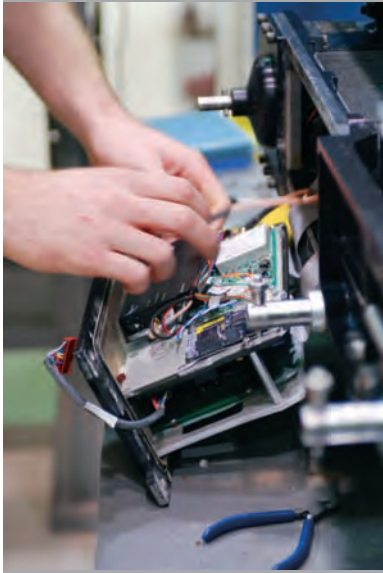


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UNCLASSIFIED

UNMANNED GROUND SYSTEMS ROADMAP

ROBOTIC SYSTEMS JOINT PROJECT OFFICE





Robotic Systems Joint Project Office

Unmanned Ground Systems Roadmap

July 2011

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2011 RS JPO Roadmap Executive Summary

The 2011 Robotic Systems Joint Project Office (RS JPO) Road Map is a biennial publication and this second edition follows the inaugural 2009 edition. The 2011 edition incorporates the roadmap addendum published in July 2010.

The RS JPO is a dual service organization reporting to the Program Executive Office for Ground Combat Systems (PEO GCS) and the Marine Corps Systems Command (MARCORSYSCOM) as the executive agencies for the acquisition of unmanned ground systems. As with the first Roadmap edition, this document will serve as a practical reference to assist in Warfighter requirements definition, identify relevant technology maturation and to focus Science and Technology (S&T) investment on Warfighter needs.

Many changes in the Department of Defense (DoD) strategy for robotic acquisition as well as the structure of the RS JPO have occurred within the last 18 months. Perhaps the most significant is the development of the Joint Initial Capabilities Document (ICD) for Unmanned Systems which defines the need for broad unmanned capabilities across air, ground and maritime domains. The ICD enables exploration of greater capabilities generation than those found in current Programs of Record (POR). This will also help to expand the more “niche applications” currently fielded based on Operational Need Statements (ONS) and Joint Urgent Operational Need Statements (JUONS). In February 2011, the Army Training and Doctrine Command (TRADOC) submitted the ICD into Joint Requirements Oversight Counsel (JROC) phase two staffing. To enhance the Voice of the Customer and define more specific Warfighter needs, TRADOC’s Army Capabilities Integration Center (ARCIC) designated the Maneuver Center of Excellence (MCoE) at Ft. Benning, GA as its “lead agent” to synchronize and coordinate robotic needs across all Army Centers of Excellence (CDEs).

In addition to the staffing advancement of the ICD, in January 2011 the program charter for all Army unmanned ground vehicles (UGVs) within Program Executive Office Integration (PEO-I) (formerly Future Combat Systems) was transferred to the RS JPO. Under this reassignment, the Small Unmanned Ground Vehicle (SUGV) XM1216, Autonomous Navigation System (ANS) and Common Mobility Platform (CMP) were transferred for procurement, fielding and life cycle management to the RS JPO. This addition to the RS JPO portfolio now creates programmatic activities in both Huntsville, Alabama and Warren, Michigan.

Recent significant events for the RS JPO include the Milestone C Decision approval for the M160 Anti-Personnel Mine Clearing System (APMCS) on 12 May 2011. This action will permit full implementation of system supportability requirements, configuration management, and additional system purchases based on resourced requirements. The Marine Corps’ Route Reconnaissance and Clearance (R2C) robotic program, the first Marine Corps POR managed by the RS JPO since its move to Warren, Michigan in 2008, is approaching its Milestone Documentation Decision (MDD) and Request for Proposal (RFP) phase. Additionally, the SUGV XM1216 was delivered to the First Unit Equipped (FUE) in March 2011 and is expected to be deployed to combat later this year.

The RS JPO Project Manager’s overarching priorities and commitments remain world-wide support to the Warfighter, support to our team members with developmental opportunities, finalizing the transition of former PEO-I personnel and programs, and continuous process improvement.

Chapter 1: RS JPO Goals and Vision: 2011–2020

1.0 Roadmap Background

The RS JPO initiated the development of an Unmanned Ground Systems Roadmap in August 2008 soon after the Project Office moved from Huntsville, AL to Warren, MI. The intent of the first version of the Roadmap was to establish a baseline for the goals and mission of the RS JPO. The 2011 edition will build off this baseline with an added emphasis on strategies as well as a continued focus on the following:

- Providing insight to the Warfighter and acquisition community on Unmanned Ground Systems (UGSs) managed by the RS JPO
- Forecasting technology growth areas based on developments within the S&T communities
- Identifying needed capabilities or areas of improvement based on previously fielded systems
- Keeping the S&T community informed regarding technology being researched or used to improve the current UGV fleet in a hope to reduce redundancy in S&T projects.

The main goal of the 2011 Unmanned Ground Systems Roadmap (2011-2020) is to convey the RS JPO's short- and long-term strategies. The short-term period covers one to five years, with long-term covering beyond five years. The RS JPO is focusing heavily on the improvement and modernization of the current robot fleet, as well as assisting in the development and release of emerging requirement documents such as the Squad Multi-Purpose Equipment Transport (S-MET). These efforts support the achievement of RS JPO's overarching goal of ensuring the Warfighter's needs are addressed both now and into the future. Along with these goals, this 2011 Roadmap is intended to inform the various stakeholder communities consisting of S&T Labs, other Program Managers (PMs), and the TRADOC CoE regarding:

- Advancements in technologies for UGS
- Changes within the organization of the RS JPO
- RS JPO interoperability efforts
- Updates on the RS JPO Commercial-off-the-shelf (COTS) and POR robotic programs

1.1 Major Events since Release of the 2009 UGS Roadmap

Since the release of the 2009 RS JPO Roadmap, several important events have taken place that resulted in a growth of manpower and responsibility within the RS JPO. The following is a partial list of events:

- On 24 November 2009, the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA[ALT]) issued the "U.S. Army Policy for the Acquisition of Unmanned Ground Systems and Integration of Mission Capability Packages," directing the RS JPO to be the focal point for all future U.S. Army UGS acquisition efforts
- An ICD to leverage existing robotic strategies and JUONS/ONS to define the capabilities and operational performance criteria required is currently in JROC staffing. This ICD provided a basis from which Capability Development Documents (CDDs) and Capability Production Documents (CPDs) for unmanned capabilities can be supported and from which PORs can be facilitated when necessary
- The RS JPO formed a Government/Industry Working Integrated Product Team (WIPT) to focus on Interoperability and address the concerns stated in the ICD
- The Office of the Secretary of Defense (OSD) developed and published the OSD Integrated Roadmap which focuses on the Services' S&T development efforts and Unmanned Systems (UMS) program projections out to 25 years

Additional information on these developments can be found in the July 2010 Addendum to the 2009 RS JPO Roadmap.

1.2 RS JPO Mission

The RS JPOs mission is to “Lead the development, systems engineering, integration, acquisition, testing, fielding, sustainment and improvement of unmanned systems for the Joint Warfighter to ensure safe, effective and supportable capabilities are provided while meeting cost, schedule and performance.”

The strategy for accomplishing our mission is a multi-tiered plan involving both near- and long-term strategies. Essential to this plan are robotic modernization and interoperability. Modernization allows for the upgrade and implementation of technology that increases system functionality and reliability. Planning for interoperability ensures that our current systems as well as future systems are able to communicate with other manned and unmanned systems and function without interference on the battlefield. Critical to modernization and interoperability is the understanding of the Warfighter’s needs, wants and desires. The ability to support and maintain our fielded systems with internal resources affords us the opportunity to gain insight into operational gaps. The ability to develop, collect, and align technology to fill operational gaps enables the RS JPO to meet its mission. With RS JPO systems deployed to Operation Enduring Freedom (OEF) and Operation New Dawn (OND), a wealth of information has been collected on potential areas for improvement and enhancement. These areas include power sources, battery life, communications, situational awareness, and more versatile tools.

1.3 RS JPO Partnerships

The RS JPO works closely with many different organizations that support the robotic mission. These working relationships have lead to partnerships being established to determine or refine robotic requirements as well as improve fielded robots and fulfill emerging urgent robotic requirements. Organizations such as TRADOC, Research, Development and Engineering Command (RDECOM), Joint Ground Robotics Integration Team (JGRIT), Naval Explosive Ordnance Disposal (EOD) Technology Division (NAVEODTECHDIV), Rapid Equipping Force (REF), and Joint Improvised Explosive Device Defeat Organization (JIEDDO) are prime examples of partnering organizations that the RS JPO has established working agreements with to ensure the smooth transitioning of technology and products.

1.3.1 RDECOM, Academia, Industry

Given the RS JPO’s close working relations with academia, industry partners and the RDECOM Labs, the RS JPO has been able to rapidly engage in modernizing current capabilities with advanced technology. Having the ability to reach out to the S&T communities with operational issues has allowed the RS JPO to quickly bring forth innovative technologies to the Warfighter. A recent example of this synergy is the development and integration of the Universal Antenna Mount (UAM) for the RG 31 Mk5E Route Clearance vehicle and the Joint Explosive Ordnance Disposal Rapid Response Vehicle (JERRV). The need for a capability to control robotic systems from the safety of armored vehicles was identified in JUONS 00333. The RS JPO worked with PM Assured Mobility Systems, CERDEC, and TARDEC to determine the best mounting location, type of mount, cable routing, and operator tie in points giving a full plug-and-play capability to the robotic operator. The upfront partnering of UAM contributing organizations allowed for the UAM to begin fielding in fewer than 12 months. In addition to collaborating for development work, the RS JPO also partners with RDECOM labs through the Small Business Initiative Research (SBIR) and Cooperative Research and Development Agreement (CRADA) processes to enhance and improve currently fielded robotic technology. Using the SBIR or CRADA process, labs will typically request the RS JPO to review and endorse robotic initiatives being pursued

with industry to ensure they are aligned with the Warfighters current needs. The RS JPO assists by providing robotic test assets, assisting in the research, and participating in the final technology reviews.

1.3.2 Rapid Equipping Force (REF) and Joint Improvised Explosive Device Defeat Organization (JIEDDO)

Along with partnering with development organizations, the RS JPO routinely partners with the REF and JIEDDO who function as rapid acquisition organizations specializing in providing materiel solutions to niche problems. Given that the majority of the fielded robotic systems have been fielded under a rapid acquisitions structure, the established working relationship between JIEDDO and REF has been well defined. The RS JPO is currently working with both organizations on several initiatives aimed at filling operational gaps being experienced by the Warfighter in OEF. Efforts such as a light weight reconnaissance robot and a culvert exploring robot are currently underway, and are leveraging the talents and experience from each organizations core competency.

1.3.3 RS JPO/Army Capabilities Integration Center (ARCIC) Partnership

The RS JPO works with ARCIC and ASA(ALT) as a partner in cradle-to-grave material solution development to ensure the timely release of products to the Warfighter. Our close ties with TRADOC's CoEs have allowed the RS JPO to be closely involved with the development of emerging requirement documents. As a result, lessons learned from the RS JPO's feedback from the field are integrated into requirements documents as they are being developed. Our participation in the Joint Ground Robotics Integration Team (JGRIT) allowed us to ensure that key interoperability requirements and future growth needs were cemented into the Unmanned Systems ICD. Having these requirements within the ICD will provide us the "hooks" to mature technology such as modular payloads, modular radios and a common controller. The Project Manager's (PMs) insight into technology maturation and potential materiel solutions for required capabilities drive a cost as an independent variable (CAIV) trade study process to articulate to the Warfighter what capability can be delivered at what cost.

1.3.4 The Joint Ground Robotics Integration Team

An important event that significantly affected Unmanned Systems was the designation of the MCoE as the TRADOC lead for ground robotics (21 July 2009). As a result, the JGRIT was established to synchronize ground robotic development and integration efforts across the DoD. The JGRIT consists of members from TRADOC's CoEs, Army labs, Marine Corps Warfighter Lab (MCWL), and other DoD components. These core members assembled and authored the Unmanned Systems ICD (November 2009). The overarching Unmanned System ICD provides a unifying strategy for the development and employment of interoperable unmanned systems across all domains and every Warfighting function. This ICD defines a required set of capabilities, to be further defined within subsequent CDD or CPDs. The goal of the JGRIT is to field technologically advanced unmanned systems. The RS JPO plays a vital role in the development and integration of such technologies.

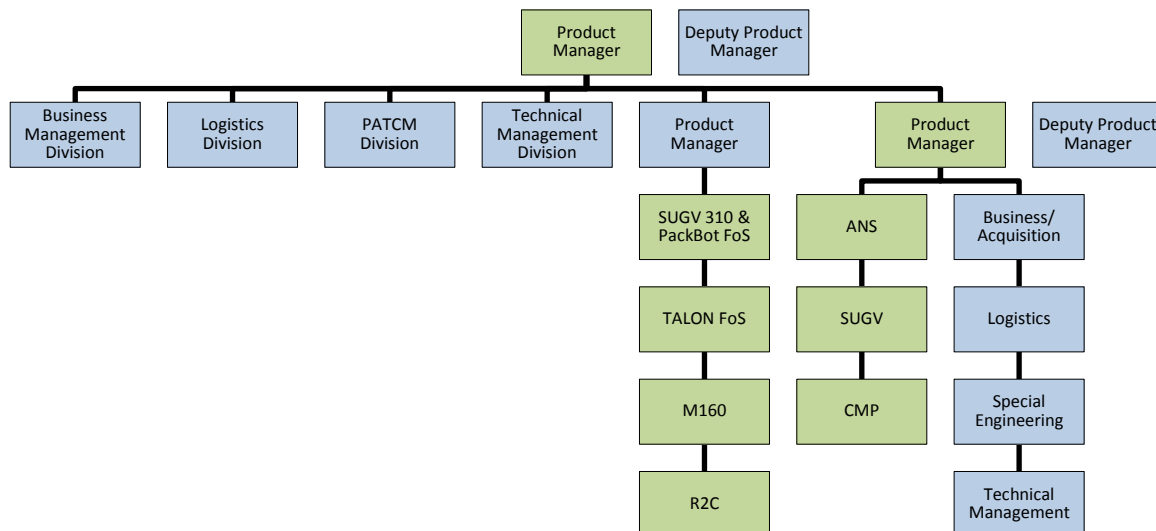
Given the common goal of smoothing the technology transition, TRADOC, the CoEs, MCWL, RS JPO, labs, and partners are now better aligned to accomplish the goal of developing and integrating advancing technologies onto UGSSs. Upcoming experiments, such as the Army Expeditionary Warfighting Experiment, are focused on emerging technologies and concepts. These experiments are primarily network-enabled and provide a venue for aggressive experimentation. The output of these experiments feed requirement documents and the development of tactics, techniques and procedures (TTPs). By linking these experiments to critical programs and the modernization plan, the RS JPO, TRADOC, and the U.S. Marine Corps Combat Development Command (MCCDC) will have the ability to enhance program objectives and quickly get equip-

ment to the hands of the Warfighters. Other experiments may be conducted in a similar manner, or through modeling and simulation (M&S), in order to support current and future developments, as well as provide insights and influence changes to various development documents.

1.4 RS JPO Organizational Structure

The RS JPO Project Manager (PM) and Deputy Project Manager (DPM) are currently supported by two Product Managers (PdMs) and four Divisions, as reflected in Figure 1, RS JPO Structure. The PdMs are responsible for managing the current fleet as well as emerging programs. The PdMs are supported by Assistant Project Managers (APMs) and Product Integrators (PIs) who manage the day-to-day activities associated with the various robotic platforms. The functional divisions within the RS JPO provide support to the PdMs and APMs in the areas of Business Management, Logistics, Technology, and Product Assurance, Test and Configuration Management (PATCM). Outreach support is provided by RS JPO Liaison Officers, which have been strategically placed at the CoEs and various other key organizations.

Figure 1. RS JPO Structure



Recently, as a result of the transition plan signed by PEO GCS and PEO-I and approved by the Army Acquisition Executive, the RS JPO organization has grown to include the former UGS portion of the PEO-I portfolio. The APMs for the ANS, SUGV and CMP are currently located in Huntsville, Alabama and have been fully integrated into the RS JPO organizational structure as of 5 January 2011.

1.4.1 APM and PI Roles and Responsibilities

The RS JPO recently restructured internal APM assignments. The APMs moved from mission specific roles to a product based alignment. The new APM roles were initiated as of 1 October 2010. There are currently seven APMs and one PI on staff supporting two PdMs, as shown in Figure 1.

The APMs/PIs are accountable for meeting project/system cost, schedule and performance objectives. With the support of cross-functional integrated product teams (IPTs), APMs are responsible for project scope, risk management, budget, achievement of requirements, resource support, and resolving and mitigating issues that could threaten the effective achievement of project objectives. As managers of the RS JPO's programs, APMs/PIs are the principle interface with the user community and acquisition stakeholders. The APMs/PIs management and execution strategy are

provided in greater details in Appendix-A, RS JPO Systems/Programs Portfolio. The following paragraphs provide a basic system description of the APM/PI programs.

1.4.1.1 APM – M160 APMCS

The M160 APMCS is a component system in the Area Clearance Family of Systems (FoS) that was developed to support the U.S. Army Area Clearance Family of Systems CPD, approved by the Headquarters, Department of the Army (HQDA) Revision 1, 11 March 2010. The CPD establishes a need for an Area Clearance FoS to clear anti-personnel (AP) landmines from urban areas, fields, forests, unimproved roads, riverbanks, and muddy areas. The M160 is a legacy, contingency system which transitioned to a post-Milestone B, Acquisition Category (ACAT) III Non-developmental Item (NDI) program.

1.4.1.2 APM – PackBot Family of Systems

The PackBot Family of Systems are small robotic platforms designed to provide the Warfighter with standoff to inspect and clear suspicious objects during improvised explosive device (IED) sweeps. These systems generally include a remote controlled articulated arm with a gripper and a pan/tilt color surveillance camera.

1.4.1.3 APM – TALON Family of Systems

The TALON Family of Systems are medium robotic platforms designed to provide the Warfighter with standoff to inspect and clear suspicious objects during IED sweeps. These systems generally include a remote controlled articulated arm with a gripper and a pan/tilt color surveillance camera.

1.4.1.4 APM – Route Reconnaissance and Clearance (R2C) Robot Program

The R2C program fulfills the requirements of the U.S. Marine Corps (USMC) R2C FoS CPD dated 29 July 2009. The R2C capability set is a FoS that will provide standoff capability for identification and interrogation of enemy mines, IEDs, and obstacles along routes, in the Marine Air-Ground Task Force area of operations.

1.4.1.5 APM – MARCbot IV/IV-N

MARCbot IV is a low cost, wheeled reconnaissance robot designed to provide the Warfighter with a highly mobile pan/tilt color camera.

1.4.1.6 APM – Appliqué Kits

The Appliqué Kits are robotic systems that can be used to convert fielded and future manned systems into unmanned systems. These systems are envisioned as „kits“ that include all of the hardware (sensors, cables, actuators, control station, etc.) and software required to fully operate and monitor the selected vehicle remotely.

1.4.1.7 APM – Common Mobility Platform (CMP)

The CMP is a 3.5-ton unmanned ground vehicle comprised of a CMP (chassis) which can carry lethal Mission Equipment Packages (MEPs), Counter-Improvised Explosive Devices (C-IEDs) MEP and sensors to include the ANS. The CMP and its MEPs will provide the maneuver platoon with an armed unmanned capability, and the maneuver company with the capability to detect, mark, and report IED. The CMP is capable of tele-operation and semi-autonomous operation through the use of a remote controller. Semi-autonomous navigation will include wireless leader/follower and waypoint navigation.

1.4.1.8 APM – Small Unmanned Ground Vehicle (SUGV) – XM1216

The SUGV, designated as XM1216, is a lightweight, soldier-portable robot capable of conducting military operations in urban terrain, tunnels, sewers, and caves. The SUGV provides Situational Awareness/Situational Understanding (SA/SU) and Intelligence, Surveillance and Reconnaissance (ISR) to dismounted soldiers enabling the performance of manpower-intensive or high-risk functions without exposing soldiers directly to the hazard. The SUGV modular design allows multiple payloads to be integrated in a plug-and-play fashion.

1.4.1.9 APM – Autonomous Navigation System (ANS) – XM155

The ANS, designated as XM155, is the mission sensor and computational package that will be integrated on the CMP (or other chassis) to provide robotic semi-autonomous capability.

1.4.2 RS JPO Liaison Officers (LNOs)

Through the use of dedicated LNOs, the RS JPO works with and maintains close relationships with Marine Corps System Command (MCSC), TRADOC, JIEDDO, REF, MCCDC and the various CoEs. The RS JPO has placed LNOs in the aforementioned key organizations to act as facilitators for the RS JPO and the robotics community. The evolution of the LNO relationships has significantly enhanced technology development efforts, requirement development efforts, and the fielding of UGVs for the Warfighter. In addition to their individual taskings, the general roles and responsibilities of the LNOs are:

- Support the exploration of capability gaps
- Ascertain the extent to which Warfighter needs can be achieved by unmanned systems
- Execute acquisition planning and interagency coordination
- Provide strategic vision for out year program efforts
- Provide mission related subject matter expertise (SME) on the acquisition and management of robotic systems and the Joint Capabilities Integration and Development System (JCIDS) process
- Serve as the user representative at ground robotic working groups, IPTs, Interface Coordination Teams, experiments, demonstrations, source selections, user juries, etc.
- Aid in the development of Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) analyses for robotics, as well as the Concept of Operations (CONOPS) and TTP development efforts for robotic equipped units
- Aid in the management of other cost, schedule and performance challenges associated with robotic systems

The RS JPO's Liaison officers and supported organizations which they support are identified in Figure 2.

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Figure 2. LNO Activities



1.4.3 RS JPO Divisions

1.4.3.1 Business Management Division

The Business Management Office (BMO) provides budget, cost, financial execution, and procurement support to the RS JPO. The office is comprised of budget, cost, and contracting personnel. BMO also manages security, site visits, clearances, property (hand receipts), phones, and facility work orders. Funding is managed across several appropriations, and all funds coming in and going out of RS JPO are reviewed for accuracy and fiscal soundness. The continuing commitment of the BMO is to ensure that PM fiscal responsibility is executed in compliance with regulations, policy, and law. Other BMO responsibilities include the following:

- Program Objective Memorandum (POM) planning and tracking
- Preparation of obligation plans
- Preparation of budget exhibits (program and resources forms)
- Execution of funds
- Credit card oversight and approval
- Transportation oversight
- Defense Travel System funding approval and oversight
- Acquisition strategies and plans
- Contract oversight and liaison with the Acquisition Center
- Systems Engineering, Testing and Analysis support planning and oversight
- Annual Review of Management Internal Controls Plan
- Military Equipment Valuation
- Preparation of annual Weapon System Review briefing packages
- Support of Annual Program Reviews to the Milestone Decision Authority (MDA)

- Should/Will Cost reporting
- Assistance with the development and review of Milestone (MS) documents for financial, cost and budgetary information
- Track cost, schedule and performance objectives for APMs

The BMO budget personnel have a number of initiatives to improve the way we do business:

- Implemented travel process change to incorporate budget review of authorizations and vouchers, which resulted in a reduction in the number of errors that cost both the government and the traveler money and hardship. This procedural change allowed the PM to better track, report and forecast future travel costs.
- Streamlined shipping procedures. In FY11, the RS JPO started utilizing Department of the Army (DA) centrally funded Transportation Account Code (TAC) codes for all Second Destination Transportation (SDT) shipments resulting in a reduction of required PM funding as well as adherence to DA centralized funding practices.
- Instituted automatic routing of credit card orders through the Budget Team prior to committing/obligating funds. This streamlined budget review of all credit card orders and ensured that the correct Element of Resource (EOR) and Job Order Number (JON) were used and funded against the correct appropriation.

The Business Management Division will be facing new challenges in the next several years:

New Financial Systems

In January 2012, the General Fund Enterprise Business System will replace legacy Army financial systems. Plans are underway to train RS JPO personnel for a smooth transition.

The RS JPO was chartered in a memo by the Army Acquisition Executive as the centralized PM with the responsibility for the acquisition life-cycle, to include budgetary and POM execution, for unmanned ground systems. As a result, the RS JPO may accept a POM for Marine Corps funding; therefore, BMO staff are learning the USMC funding systems and POM process to accept and execute the funding.

Overseas Contingency Operations (OCO) Funding Drawdown

With OND drawdown efforts underway, the shift of funding to cover the increased costs of Robotics in Afghanistan must be executed. As Operations and Maintenance, Army (OMA) OCO funding becomes more scarce, RS JPO will have to transition the funding from OCO, then to “Base dollars” then to POM for sustainment costs.

DoD Efficiency/Affordability Initiatives

OSD launched a comprehensive effort to reduce the DoD’s overhead expenditures. The goal was, and is, to sustain the U.S. military’s size and strength over the long-term by reinvesting those efficiency savings in force structure and other key combat capabilities.

The BMO’s Acquisition Team will be implementing the Defense Acquisition Executive’s (DAE) Better Buying Power initiatives in all current and future efforts. Specifically, the BMO will promote real competition at all stages of the contracting process by minimizing the use of sole-source contracts, ensuring that requirements are properly documented and limiting the period of performance in non-competitive actions.

The DAE also targets affordability and controls cost growth through several efficiency initiatives. All programs were directed to establish “Should Cost” estimates for ACAT I, II, and III PORs. In addition, all PORs must have annual portfolio Program Reviews with the MDA.

Research, Development, Test & Evaluation (RDT&E) requirements

Currently there is no RDT&E funding line in the RS JPO, except for programs that recently transitioned from PEO-I. To fulfill the Congressional goal that one third of ground vehicles would be Robotic by 2015, funding for new RDT&E efforts is necessary. Robotic integration, technology advancements, interoperability, and testing are some of the efforts that require RDT&E funding.

New Robotic Programs

The RS JPO is currently working on establishing new PORs. Life cycle cost estimates, business case analyses and program office estimates are but a few of the required documents that must be developed as part of the Milestone Decision process. With these additional functions, RS JPO must identify and manage the growth of BMO personnel due to new missions such as R2C, S-MET, Appliqué, SUGV, and other future robotic requirements.

1.4.3.2 Logistics Division

The RS JPO logistics mission is to develop the proper logistic support strategies and provide sustainment for all fielded robotic systems whether in the continental United States (CONUS) or outside the continental United States (OCONUS). All sustainment logistic activities are managed by the RS JPO's Joint Robotics Repair Fielding Activity (JRRF). Army Materiel Command was tasked by HQDA for accountability and sustainment for all Theater Provided Equipment (TPE) for Joint Forces operating in Operation Iraqi Freedom (OIF) and OEF from July 2004 until resolved. As a result, the RS JPO/JRRF provides sustainment for all unmanned ground vehicles in the U.S. Central Command (CENTCOM) area of operations as well as CONUS training centers. Alternative methods of robotic support being explored include outsourcing of parts repairs to a non-original equipment manufacturer (OEM) contractor. The JRRF will continue to develop and refine repair processes and serve as the center for technician support for all detachments and training sites. For PORs, specific requirements for meeting Warfighter support performance, and sustainment requirements for the life of the system are found in AR 700-127, Integrated Logistics Support. With the anticipated growth of PORs within RS JPO, the acquisition of future systems must comply with the Total Life Cycle Sustainment Management process to ensure reliability, availability, and maintainability.

In order to provide forward support to UGVs, the RS JPO operates multiple robotic maintenance facilities around the world; including Joint Robotic Repair Detachments (JRRD) in Iraq and Afghanistan. The JRRDs were established to fill a maintenance capability gap created by the acquisition and employment of COTS robotic systems in both theaters. These organizations operate outside of the normal Army force structure to provide pre-deployment training, issue, and repair of robotic equipment. The facilities are staffed with a mix of active duty service members, reservists and contractors.

The challenge with the fielded robotic systems is that they are not managed and maintained like other typical platforms in the Army inventory. The operational urgency of need and uniqueness of these platforms required a non-standard approach to integrating these technologies into the active force. The RS JPO sustainment strategy for the fielded robots includes improvements and upgrades to current platforms with the latest technologies. Due to the drawdown from OND, RS JPO is developing a responsible drawdown strategy that includes long term storage and/or disposition of robotic systems.

The Army lacks adequate maintenance doctrine to address the unique technologies and other sustainment issues associated with robotic systems. Robotic maintenance doctrine has not been delineated in Army doctrine. Only a small group of operators and personnel within the Army, involved with the development, testing, and acquisition of robotics technologies, are well acquainted and/or understand their impact. The RS JPO is initiating efforts to improve the process

of robotic data maintenance, collection, and analysis, decreasing top sustainment cost drivers, and outsourcing repairable parts. By improving the way data is collected, analyzed and input into the Cataloging Ordering Logistics Tracking System (COLTS), the JRRF hopes to increase mean time between failures and identify systemic parts problems which will reduce the number of parts consumed. The RS JPO is currently working with the OEMs to analyze the repair versus replace cost of our top sustainment parts cost drivers to determine if the contractual Return Maintenance Actions are being utilized efficiently.

Training

Currently, the Army trains most of the skills required to support robotic technologies. However, it is neither from a systems approach nor is there a Military Occupational Specialty (MOS) identified or designated to perform this function. The RS JPO logistics training division provides training on robotic platforms associated with COTS and PORs. This includes but is not limited to: conducting operational assessments; conducting COTS and POR system operator training; and supporting doctrine and tactics training, mobile training teams (MTT) and new equipment training (NET). Training is currently provided from Ft. Leonard Wood, Missouri and the JRRF at Selfridge Air National Guard Base (SANGB), Michigan.

United States Army Forces Command (FORSCOM)

The RS JPO is working with FORSCOM to address the robotic training capability gap. This effort is still in its infancy. FORSCOM requires robotic capabilities at multiple FORSCOM home stations to assist units in the planning and execution of individual and collective robotics training as part of the “Defeat the Device” Line of Effort. This period of persistent conflict has stretched operational forces, creating a gap in the ability of combat units to plan and execute effective robotics focused C-IED training. This gap is exacerbated by the diversity of threats in the operational environment, the introduction of multiple non-standard capabilities, key personnel turnover, minimal manning during the reset phase of Army Force Generation (ARFORGEN) process and short dwell time limiting individual and collective training opportunities. The initiative is being applied to Home Station Training Lanes at designated FORSCOM installations. RS JPO, in cooperation with FORSCOM, has selected Ft. Hood as a Proof of Concept to implement this initiative. The basis for this initiative is to train the Warfighter prior to going to the Combat Training Centers. The more exposure the Warfighter gets on the robotic systems, the better they will understand the functionality, capabilities of the platforms, and how execution of missions using robotic platforms are performed.

In order to be successful in managing new robotic technologies, RS JPO must understand new system impacts and be prepared to support units employing robotic technologies in the near and long term. RS JPO will posture itself to incorporate UGVs (both COTS and POR) into standard Army Logistic Information Systems. To further support these efforts, the RS JPO must become part of the mandatory pre-deployment requirement for training robotic operators, and establish courses to work in conjunction with a unit’s ARFORGEN schedule. One alternative being explored is to establish a robotic school with TRADOC that provides trained operators on multiple platforms within one course. This course would fill the gap between FORSCOM and TRADOC, thus allowing FORSCOM to tap into a TRADOC sanctioned course that would provide them with trained operators to use robotic systems at their Home Station Training Lanes and in their ARFORGEN schedule. This would also help to reduce the logistical footprint required to maintain MTTs and equipment. As systems evolve into PORs, this course would establish the basis of the operator New Equipment Training Team.

1.4.3.3 Product Assurance, Test and Configuration Management (PATCM) Division

The mission of the PATCM Division, within the RS JPO, is to provide testing, evaluation, quality assurance, and configuration leadership to all phases of the robotic systems development, integra-

tion and deployment. PATCM's short term strategy is to continue supporting Rapid Acquisition Initiatives (RAIs) of COTS systems, such as TALON and PackBot, while supporting development of future robotic programs.

Continued support will be provided to future RAI and fleet modernization to ensure the systems are fully tested to verify safety and qualified to meet performance and reliability requirements as set forth in the System Performance Specifications. For current RAI robotic systems identified as having long term sustainment requirements (beyond current theater use), PATCM will work with the Army Test and Evaluation Command (ATEC) to develop the test and evaluation processes to support the conversion of COTS systems/PORs.

Through cooperation with ATEC, the RS JPO (PATCM) will develop strategies for the testing and evaluation of future UGVs. The range of autonomous functions will span from self-righting and return-home capabilities to fully completing a mission without human interface. Autonomous capabilities have little testing precedence and, as a result, practices and procedures on testing will need to be defined and formalized. Several efforts are currently underway to facilitate planning between RS JPO and ATEC to address issues and develop overarching test strategies.

Maturing quality metrics is another goal for PATCM. This is accomplished through a two-step process. Initial steps will involve defining key metrics, improving data recording accuracy, validating data, and reconciling internal databases with other DoD databases (COLTS, Product Quality Deficiency Report [PQDR], Product Deficiency Reporting and Evaluation Program [PDREP], Acceptance Database, etc.). Future efforts will include developing automated reporting capabilities to accurately report performance metrics of the various robotic platforms so that resources can be properly focused on key quality improvement opportunities.

Lean Six Sigma initiatives are underway within the RS JPO and PATCM will be supporting this effort by incorporating the projects with other process improvement initiatives. An initiative to better catalogue and control milestone documentation is underway within the RS JPO. It was volunteered to be the pilot program for PEO GCS with output from this effort standardizing documentation requirements throughout PEO GCS.

PATCM has recognized the need to provide consistent quality guidance in new contracting efforts. Because the preponderance of the products currently managed by the RS JPO are either COTS or NDI, it is important that our contracts provide added flexibility and increased accountability. As a direct result of lessons learned, future robotic contracts will be more quality focused. Standard contract language has been developed and will continue to be updated. Contract language will address, where appropriate:

- quality management systems
- corrective and preventive action
- configuration management
- test and evaluation
- inspection and acceptance
- warranty

Process Excellence Program (PEP)

The PEP is being developed within the RS JPO to identify, control, measure, and improve processes important to the success of the entire RS JPO. The PEP will build upon quality improvement initiatives already in place (e.g., Lean Six Sigma, Command Maintenance Management Inspection [CMMI]) and complement PEO GCS efforts through close coordination and information exchange. The PEP will add structure to the organization to help define and incorpo-

rate best practices, lessons learned and allows the organization to make decisions based on the best available data.

PATCM will facilitate this initiative by establishing an implementation plan, providing training, leading the Overarching Integrated Product Team, and providing regular updates to management. Additional Integrated Product Teams will be formed to address the key processes defined by management. At some point, each member of the organization will provide input into the program. PATCM will facilitate all the process teams to ensure the success of the program. These efforts will culminate in a defined repository for process documentation and an internal audit verifying compliance to the program.

The plan incorporates a two-phase approach. Phase 1 included completed implementation for both the Warren and Selfridge operations by the end of the first quarter of FY12. Phase 2 will be completed by the end of FY12 and will include the remainder of the RS JPO operations: CONUS and OCONUS JRRDs, LNOs, and Huntsville. This is a highly aggressive schedule that requires dedicated resources.

PATCM Long Term Strategy

PATCM's long-term strategy aligns with the Army Campaign Plan for Unmanned Ground Vehicles. The campaign plan requires future UGVs capabilities to include a net-centric requirement, varying degree of autonomy, and potentially weaponized platforms. Therefore, future test and evaluation will need to take into account net-centric systems, increased levels of autonomy, and armed systems. This will pose unique requirements for evaluation criteria, test methodology, and test site layout resulting in increased up-front test planning efforts. M&S will play a critical role in evaluating autonomous vehicles; physical models alone cannot provide the depth of evaluation required. The software-intensive systems will require multiple iterations of many different scenarios to a given requirement. The only economically feasible way of accomplishing this is through M&S. Models will be required to have a high degree of confidence before a robust simulation program is conducted. This will require a high level of collaboration with ATEC to ensure models used will fulfill evaluation needs through validation and verification. In addition to stand-alone robotic systems, the testing and evaluation of hybrid systems (e.g., remote operation, supervised and fully autonomous appliqué kits on existing vehicle platforms) will pose unique inter- and intra program office and joint service considerations for testing that will need to be addressed.

The PATCM goal for quality assurance is to have a robust quality metric system in place in three to five years that will continue to evolve. This system will provide a complete cradle-to-grave quality metric tracking history.

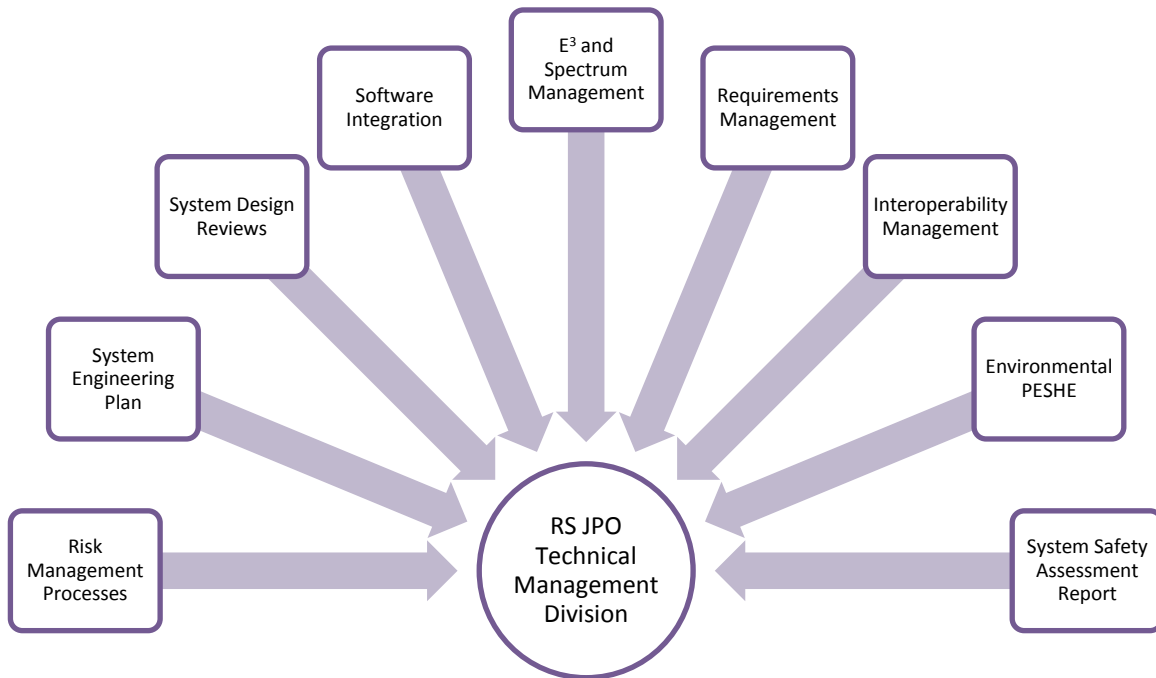
1.4.3.4 Technical Management Division

The mission of the RS JPO Technical Management (Tech Mgt) Division is to provide system engineering oversight, resources, processes, and tools to execute system engineering tasks and activities that enable the delivery of UGS capabilities which meet the Warfighter's operational needs through the use of specified performance requirements. Tech Mgt utilizes a disciplined system engineering approach to manage the engineering, design, development, integration, production and sustainment of UGVs. The fundamental goal of RS JPO's Tech Mgt Division is to transform the Warfighter's written and validated needs into sustainable products that meet those needs, optimized in terms of affordable operational effectiveness within the bounds of the cost and schedule constraints of each program.

To assist in the task of transforming the Warfighter requirements into materiel solutions the Tech Mgt Division uses several resources and tools, as illustrated in Figure 3 Technical Management Responsibilities. The breadth and depth of knowledge in the Tech Mgt Division is utilized to

supply expertise to the APMs and their IPTs. Tech Mgt engineers support IPTs in the areas of requirements transformation, electromagnetic environmental effects (E³) and spectrum management, software integration, interoperability, environmental and safety, developing systems engineering plans (SEPs) and chairing technical reviews. Risk management is a key element to the IPTs to both characterize and manage technical risks. Tech Mgt utilizes the PEO GCS standardized Risk Recon Tool and Risk Review Boards to support risk management in all program acquisitions. Enabling and enhancing the interoperability and modularity of all operational, functional, and physical interfaces is also a key focus area for Tech Mgt engineers.

Figure 3. Technical Management Responsibilities



S&T Collaboration is a fundamental area of Tech Mgt. Currently, Tech Mgt is working with the Army S&T community to identify near and far term technology capabilities to address Warfighter needs in robotic systems. These needs, which are identified in Chapter 3 Table 19, will be utilized to influence development efforts across the RS JPO portfolio. This collaborative environment will ensure that the Warfighter needs are being addressed in a timely and affordable manner. In the future, Technology Transition Agreements (TTAs) with the S&T community will establish agreements on how and what technology will be transitioned to the joint Warfighter robotic community. Future close collaboration is needed with all S&T areas of all the Services to ensure the Warfighter is receiving the best possible solution as efficiently as possible.

Safety

The near term task of addressing and overcoming safety concerns stemming from unmanned ground vehicles on the battlefield is something Tech Mgt (and the RS JPO as a whole) takes very seriously. Tech Mgt is focusing its efforts in this area by participating in safety working groups for autonomous technology where concerns from the unmanned system community at large are discussed and documented. Our short term strategy is to collect the safety concerns and solutions used to offset the risk posed in order to build a knowledge base of what approaches are effective. Empowered with this array of knowledge, Tech Mgt can incorporate requirements into materiel solutions for technologies that have been demonstrated to reduce safety concerns. A future evolu-

tion of the safety concerns with autonomy will be the integration of weapon systems which will be handled in much the same manner as described above.

Software

Software safety management and software integration are critical areas of the Tech Mgt system engineering process. Near term goals in this area include:

- Require performance specifications to include language to ensure OEMs are utilizing adequate Software Quality Assurance (SQA) processes
- Ensure Software Safety Critical items are documented in the OEM's Safety Assessment Reports
- Establish software system safety working groups for all POR systems

Far term goals include:

- Include Software System Safety analyses early in the program life cycles
- Include requirement for OEMs to be CMMI Level III or equivalent in all performance specifications
- Require a Software Development Plan for all software being developed for RS JPO

E³ and Spectrum

The management of E³ and Spectrum is a critical piece to the wireless operation of UGVs. Tech Mgt is responsible for defining the radio equipment attributes of UGVs based on program requirements. COTS radios are primarily used on UGVs due to the high data rate needed to support full motion video and avoid latency.

Radio equipment must be certified by Army Spectrum Management Office (ASMO) by submitting a DD-1494 form that the RS JPO sponsors on behalf of radio vendors. This is to make sure the equipment operates in appropriate, allocated frequency bands and operates within the parameters established by national and international regulations. Once the radio is certified by ASMO the RS JPO can then request frequency assignments from the Army Frequency Management Office.

Due to the inconsistency of radio spectrum usage from one nation to another and reallocation of spectrum by regulators for non-military use, radios used on UGVs need to be flexible. Recent advances in radio technology such as Software Defined Radios (SDRs) have improved the flexibility of radio systems by supporting wide or multiple frequency bands. Also internet protocol (IP) addressable radios will allow communication systems to be swapped in/out of UGVs to adapt to appropriate frequency bands.

In the near term, Tech Mgt intends to improve the RS JPO's ability to field spectrum supportable radios with continually improved performance by developing a closer relationship with the RDECOM Communications-Electronic Research, Development and Engineering Center (CERDEC). The RS JPO can leverage CERDEC's expertise in terms of communications modeling and resident knowledge.

In the long term, the RS JPO's Interoperability Effort (discussed in depth in Chapter 3) is developing a Communications Interoperability Profile (IOP). This document will include performance specifications in terms of usable frequency bands, physical connection requirements for the ability to quickly change out different radios, common messaging requirements for the selection of frequency channels and radio status messages (i.e., signal to noise ratio, power output level, etc.), and common waveform requirements. As the communications and other IOP efforts progress, the intent for the RS JPO will be to enable greatly enhanced capabilities and reduce sustainment costs

through the use of highly interoperable and modular systems. This will enable modular plug-and-play payloads, interoperability between ground and air unmanned systems, connection of ground robots into the tactical network, sharing of intelligence information to distributed users, control of multiple assets, and several other advanced Warfighting capabilities

Modeling and Simulation Management

Requirements analysis and management is key to ensuring that the system design reflects the requirements for all life cycle system elements including hardware, software and environmental. In the near term, Tech Mgt intends to leverage M&S tools to make better technical decisions and avoid spending time and resources on physical analysis when appropriate. The Tank and Automotive Research, Development and Engineering Command (TARDEC) is developing a Robotic System Integration Lab (RSIL) and Virtual System Integration Lab (VSIL) which will be leveraged for M&S of integrated robot solutions using simulated radios in simulated operational environments. The RS JPO will continue feeding their M&S tool requirements to TARDEC and will collaborate with them as the solutions are identified and implemented.

In the long term, the Tech Mgt Division will increase the use of a variety of M&S tools for different purposes. The TARDEC RSIL/VSIL construct will be used to assess the IOPs' abilities to provide real interoperable solutions, as well as to assess different commercial systems' conformance to those IOPs. The capabilities of TARDEC's Concepts, Analysis, Simulation and System Integration group will be utilized for assessing the realism of requirements and to aid in the various trade studies needed by Tech Mgt systems engineers. These may include powertrain M&S, system architecture modeling, structural analysis, survivability analysis, and thermal modeling, and can be used to generate confidence in the RS JPO's ability to successfully deliver products on time and on schedule that meet Warfighter requirements. The M&S capabilities of other S&T labs within RDECOM and the other Services will be utilized as well for other areas of expertise.

In support of the growing demand placed on increasing unmanned capabilities, a robust system engineering effort will be needed. Tech Mgt will continue to work towards the development of interoperability standards using empowered WIPTs that include representation from both government and industry. This government/industry WIPT approach has been successful in fostering a collaborative approach to the development of interoperability standards that are of mutual benefit to both government and industry.

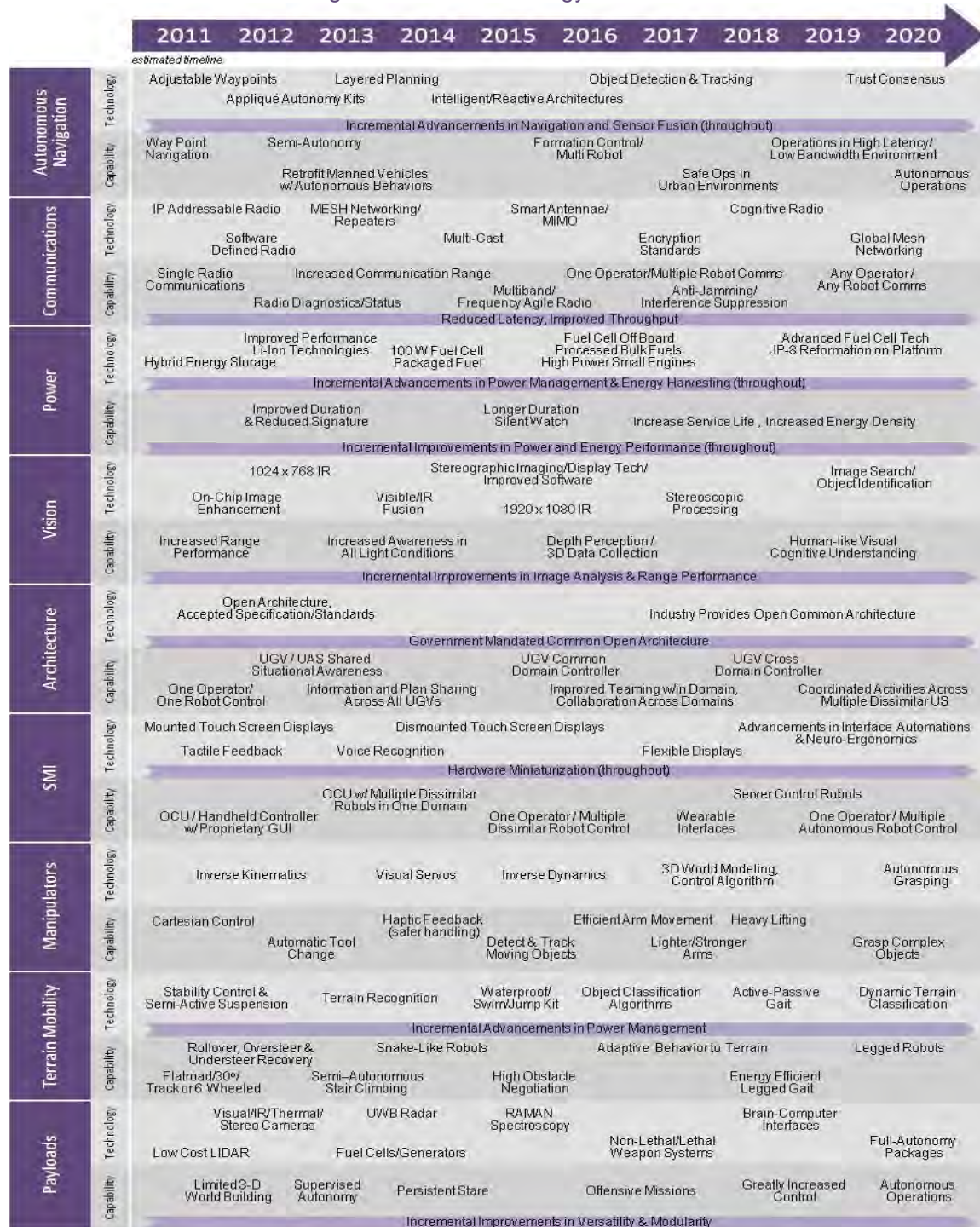
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Chapter 2: Technology Enablers/Road Ahead

2.0 Introduction

The RS JPO understands that innovation and technology will impact unmanned ground systems and may enhance the Warfighters ability to survive and adapt to the changing battlefield. The RS JPO, S&T labs, industry, and academia are continuing to work on technology advancements to enhance ground robotic capabilities.

Figure 4. UGV Technology Enablers



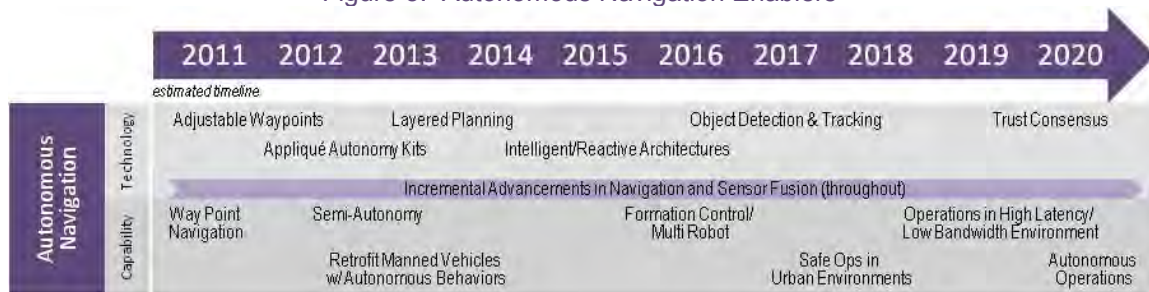
By working with Army Technology Objectives (ATO) sponsors, the RS JPO and its partner labs are aligning the S&T portfolios to the Warfighter's needs. Small businesses also play a role by working with the labs, which provide linkages and insight to upcoming technology initiatives. These efforts are the main focus of the SBIR program, where small businesses have access to government resources to conduct basic and advanced research. In addition to ATOs and SBIRs, the RS JPO hosts IPTs with a focus on standardization and Interoperability. Through these processes, the top technology enablers for Unmanned Ground Systems are identified. The top nine UGV technology enablers are:

- Autonomous Navigation
- Communication
- Power
- Vision
- Architecture
- Soldier Machine Interface
- Manipulation
- Terrain Mobility
- Payloads

The following paragraphs provide a top level discussion and a development forecast for each of the nine technology enablers. By developing, procuring, integrating and fielding unmanned ground systems, the RS JPO encourages and focuses further developments of these technologies and enhancements. This list of enabling technology is not an exhaustive list, but rather offers an illustration of the current technology and a glimpse of future capabilities for the Warfighter.

2.1 Autonomous Navigation

Figure 5. Autonomous Navigation Enablers



Description

Autonomous robots conduct tasks in unstructured environments without continuous guidance from an operator. Autonomy reduces operator workload and increases performance when communication is limited or unreliable. Object Recognition and Intelligent Navigation technologies are required to realize autonomous behaviors. These technology enablers must effectively satisfy the following capabilities:

Table 1. Autonomous Navigation Capability Needs

Object Recognition	Intelligent Navigation
Recognize combatants/non-combatants	Avoid static and dynamic obstacles
Recognize other living entities	Predict motion of dynamic objects
Recognize vehicles, roads, paths, and markers	Obey traffic regulations as appropriate

Several standards exist to define various levels of autonomy. The National Institute of Standards and Technology maintains the Autonomy Levels for Unmanned Systems Standard, which contains levels from Remote Control to Full Autonomy. A UGV may operate with various levels of autonomy based on task difficulty, environmental complexity, or required operational tempo (OPTEMPO).

Status

Autonomous Navigation is a subject of extensive research and development within both Government and Industry. Since 2009, the following activities have led to substantial breakthroughs in this technology:

Table 2. Autonomous Navigation Advancements

Major Activity	Type	Result
DARPA Challenges	Demonstration	Demonstrated long-distance autonomous waypoint following, obstacle detection and avoidance, and robotic platform endurance
MAGIC	Demonstration	Demonstrated autonomous coordination and teaming among multiple robots in operationally relevant urban scenarios
ARL Robotics CTA	Investigation	Investigated perception and intelligence for large autonomous robots
ARL MAST CTA	Investigation	Investigated autonomous air-ground teaming between small robots
CAST	Program	Matured autonomous leader-follower technologies in convoys
NAUS ATO	Program	Matured autonomous formation control and UGV self-security
SOURCE ATO	Program	Matures technologies that enable autonomous UGVs to safely operate within urban environments among humans, animals, and vehicles
AEODRS	Program	Matures autonomous navigation for Navy EOD robots
ACS, RIK, ROS, 4D/RCS	System	A set of intelligent architectures for small-robot navigation
ANS	System	A perception and control system for large UGV Programs of Record
AMDS	System	A set of payload modules that enable small autonomous robots to find, mark, and neutralize explosive devices

Industry has also demonstrated applications of autonomous driving over thousands of miles of highway, and during open-pit mining operations. Automobiles have also commercialized several autonomous driving aids such as stability control, adaptive cruise control, and self-parking. Many autonomous navigation technologies will likely mature through advancements in semi-autonomous behavior within the automotive industry.

Future Trends

Safety is a critical concern and one of the most significant issues autonomous vehicles must overcome before they can be widely accepted and fielded. Currently, autonomous vehicles operate within restricted areas in which all operators are fully aware of the vehicles' limitations. Before operation in crowded urban environments can happen, advancements in navigation and sensor fusion algorithms are needed to allow robots to distinguish humans from other objects, negotiate complex terrain, and operate. Programs such as Supervised Autonomy to Neutralize and Detect IEDs (SANDI) and Squad Mission Support System (SMSS) that are being used in the area of responsibility, are helping to evolve current technology into robust proven systems.

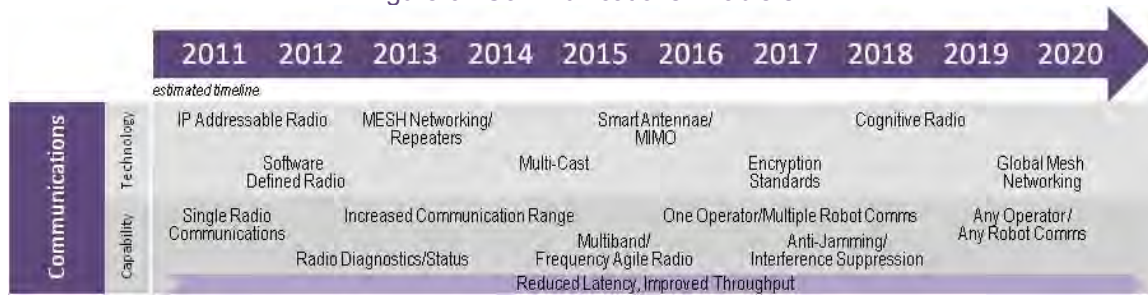
Obstacle detection is a significant capability required in order to enable the next level of advancement in Autonomous Navigation. Advancements in robotic perception and understanding enable the development of obstacle detection; and *a priori* knowledge via maps or object templates. In the long-term, such capabilities will be applied toward obstacles.

Manned vehicle platforms are prime candidates for semi-autonomous behaviors integration because of their proven reliability and prevalence in the field. In the near-term, the S&T Community are expected to accelerate efforts to develop technologies that retrofit manned vehicles with appliqué autonomy kits. The Autonomous Mobility Appliqué System (AMAS) Program is a prime candidate for such investments as it tackles appliqué autonomy at both the algorithmic and architectural levels.

In the near-term, the S&T Community should continue investments in odometry and decision support technologies to enable waypoint navigation. The S&T Community should continue to integrate semi-autonomous behaviors on small robots; and it should continue to integrate supervised autonomous behaviors onto large platforms.

2.2 Communications

Figure 6. Communications Enablers



Description

The communications link is a subsystem of the UGV that passes data between the operator control unit (OCU) and the robot processor. This is accomplished via wireless radio link or a tether. Tether communications is accomplished either over a fiber-optic cable or twisted wire, with the former being more common for UGVs as it is less susceptible to Radio Frequency (RF) jammed environments. Tether communications is usually employed when the RF environment is harsh or if transmission of RF signals is not desired.

Both communications systems provide the necessary electronics and logical interface to pass the data between the OCU and the robot processor. Current UGV systems use a closed loop link that does not share information with other networks. The OCU transmits commands and audio to the robot while the robot transmits status messages, video, and audio. The importance of this communication link cannot be over emphasized as the operator must maintain control of the robot at all times. Loss of the communications link will cause the robot to cease operations and could force the operator to be exposed to dangerous situations to re-establish robotic communications. Future autonomous capabilities, such as return to home or safe location, may alleviate concerns associated with the loss of communications.

Until recently, wireless radio communications for UGVs typically utilized three distinct radios to provide the following capabilities:

Table 3. Communications Capability Needs

Radio Capability	Description
Data Transmission	Transmits control signals from Operator to UGV
Video Transmission	Transmits analog video from UGV to Operator
Emergency Stop	Transmits signal to disable UGV

The use of separate radios to support different communications adds a level of complexity to the system and affects the size, weight and power requirements. By digitizing, encoding the video, and combining the voice and data over a single data stream, information can be transmitted over a single radio channel; simplifying the wireless communications. Radio technologies are generally designed to balance requirements in latency, bandwidth, and signal propagation. Radio Frequency Interference (RFI) from other emitting sources (including other UGVs) as well as the reduction of the number of available RF channels has led the S&T community to develop more advanced communication technologies for UGV usage.

Status

Many of the currently available UGVs utilize radios that are highly integrated into the robot architecture. These radios are generally limited to a frequency band (sometimes to a single frequency channel) which makes coordination of spectrum in CONUS and OCONUS challenging if not impossible, requiring significant hardware or software changes in order to meet spectrum guidelines. In addition, many UGV systems use unlicensed frequency bands (e.g., 2.4 GHz) that are susceptible to interference as other WiFi systems can operate in the same band with no protection. Due to interference concerns and incompatibility with Counter Remote Control Improvised Explosive Device (RCIED) Electronic Warfare (CREW), many of the fielded Army and USMC UGV assets have undergone communication radio system upgrades to new frequency bands. Higher frequency bands can support wider channel bandwidths and high data rates required for real-time teleoperation video transmission. However, higher frequencies do not propagate as well as lower frequencies and limits communications range in Line-of-Sight (LOS) and Non-Line of Sight (NLOS) conditions. The Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard is widely used for implementing wireless local area network (WLAN) computer communication and is used by some UGV radios, as the over-the-air modulation techniques work well in multi-path environments and support high data rate transmissions.

Government and Industry have recently created radio technologies to increase range, networking capabilities, and RF flexibility. The table below illustrates some of the technology development efforts in the radio communications field undertaken in the last two years by both Government and Industry labs.

Table 4. Communications Advancements

Major Activity	Type	Result
DARPA MNM	Program	Matures technologies to adapt to environment and mission yet provide higher data rates along a robust data link
JTRS HMS	System	A communication network for dismounted Soldiers, sensors, and UGVs
JTRS, WIN-T	System	A set of communication networks and waveforms for manned vehicles
CDL, DDL	System	A set of data links for air-ground communication with OSRV

Modern radios can transmit information to several target receivers simultaneously in a process called multi-cast. This process transmits information with equal quality as older single-cast tech-

nologies; and it enables collaborative behaviors to develop between robots. Many small robots and OCUs, by their nature, have low antenna heights that make radio links susceptible to multipath fading, and thereby drastically reduce radio link range and reliability. But, waveforms such as Orthogonal Frequency Division Multiplexing (OFDM) or Coded-Orthogonal Frequency Division Multiplexing (COFDM) are resilient to multipath fading and support high data rates for video transmission. OFDM and COFDM are robust in multipath environments and increase wireless range performance on UGVs. Some radios also employ frequency-hopping spread spectrum technologies that rapidly switch between different frequency channels to make the radio link less susceptible to interference and more difficult to detect.

Future Trends

In order to create more interoperable networks, UGV radios will need to support multiple waveforms and span wider frequency ranges. The continued enhancement of SDR and Smart Antenna technologies will increase the multiband capability and range of radios. These technologies will enable the radio to suppress interference or RF jamming while improving desired signal levels. These enhancements will promote Cognitive Radio (CR) technology that will adapt to the RF environment by selecting the best modulation format and frequency to support the information being relayed. On the future battlefield, UGVs will multi-cast images securely to troops and be capable of relaying data from one asset to another through a dynamic network of nodes and relays. Operators will also have the capability to assign control of payloads to secondary operators.

SDRs and Smart Antennas will increase the multi-band properties and range performance of radios. These technologies enable radios to overcome or suppress RFI and simultaneously improve signal levels. Defense Advanced Research Projects Agency's (DARPA's) Wireless Network After Next (WNaN), will likely mature CR technologies that select the frequency and modulation formats to transmit particular types of information in real-time. In the future, UGVs will also securely multi-cast information to Warfighters and relay data from one asset to another via Mesh Networks. Mesh Networks (or Mobile Ad-Hoc Networks [MANET]) technologies are self-configuring unstructured wireless networks of mobile devices in which any node can be a radio repeater that extends the range between the OCU and the robot. They can be exploited to improve NLOS communications within buildings and around obstacles without exposing the robot operator to danger.

To enable advancements in communications technology, the S&T Community should accelerate efforts to develop modeling software for radio communications and networks. Such software is required to validate radio interfaces and designs within a mature trade space; and, it enables researchers to evaluate emerging technologies such as CR and Mesh Networks. Emerging UGV requirements to operate within buildings or other enclosed spaces will further increase the need for modeling.

In addition, the S&T Community should accelerate investments to develop multi-cast communication technologies. Multi-robot coordination is a force multiplier that allows Soldiers to increase situational awareness; and multi-cast technologies allow semi-autonomous and autonomous collaboration between robots to exist. The S&T Community should continue efforts to develop radios with frequency-hopping characteristics that mitigate risks from RFI.

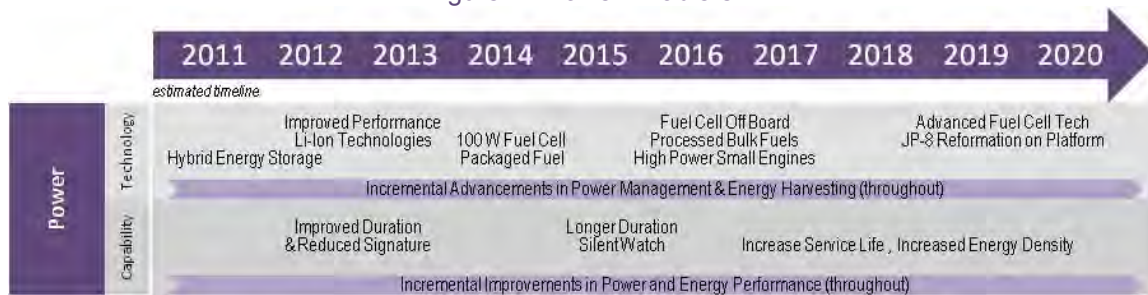
Requirements to increase interoperability between UGVs and unmanned aircraft systems (UASs) and thereby increase situational awareness represent a major shift in Army communications. Yet, radio equipment today is heavily integrated onto UGVs; and it is highly specialized to the UGV Manufacturer. As a result, the S&T Community should continue efforts to build common subsystems to enable plug-and-play functionality such that specific missions dictate radio capabilities. IP version 4 (IPv4) is the common IP standard used on IP addressable devices of UGVs, however,

IPv4 addresses are projected to run out and UGV systems will need to migrate to IP version 6 (IPv6) to support the increased demand.

Ultimately, UGV wireless communications will connect to the Global Information Grid (GIG) network and will be ubiquitous enabling users to use their cell phones to control a robot from distant locations anywhere. An ongoing effort by the DoD next generation radio communication system is the development of the Joint Tactical Radio System (JTRS), which will provide wireless connectivity and interoperability for ground mobile, man portable, maritime and airborne forces operating within the GIG. The JTRS Handheld/Manpack/Small Form Fit (HMS) program provides embedded communication that is targeted to support unmanned aerial vehicle (UAV) (Class I), Non Line-of-Sight-Launch System (NLOS-LS), Land Warrior, SUGV, unattended ground sensor (UGS), and Intelligent Munitions Systems (IMS).

2.3 Power

Figure 7. Power Enablers



Description

Current UGVs require energy dense, rechargeable, and reliable power sources in order to efficiently operate. These power sources must satisfy the size and weight constraints of the host platform, and they must satisfy a broad set of environmental and safety requirements.

The following power technologies may be used to match a given Use Profile:

Table 5. Power Use Profiles

Energy Storage	Energy Harvesting	Fuel Cells	Engines
Lead Acid/Ni-Cd	Kinetic	Solid Oxide	Gasoline
Lithium Ion	Solar	Proton Exchange Membrane (PEM)	Diesel/JP-8

A set of power technologies might also be hybridized to better match a UGV Use Profile. Such technologies will enable robots to conduct persistent stare and silent watch operations.

Status

A significant amount of research and development in both Government and Industry have been devoted to the areas of energy storage, fuel cells, and small internal combustion engines. Since 2009, the following activities have led to incremental improvements in this technology.

Table 6. Power Advancements

Major Activity	Type	Result
TARDEC ATO-M	Program	Matured domestic manufacturing capabilities for advanced Lithium Ion cell technologies and improved power and energy density

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NPS ATO-D	Program	Matured 10-kW diesel engine APU for Abrams at TRL 6
TARDEC Rotary Engine	Program	Matured 9-kW small rotary engine in an APU for Abrams at TRL 5
TARDEC Propane SOFC	Program	Matured fuel cell technologies to enhance batteries on small robots to extend mission duration between 150 - 250 W
TARDEC JP-8 Fuel Cell APU	Program	Matured fuel cell and reformation technologies to enable fuel cells to operate off of JP-8 fuel and deliver near-silent operation at 10 kW
TARDEC Advanced Batteries	Program	Matures Lithium Ion and advanced cell technologies to improve energy and power density, safety, cost and standard form factors

At present, small UGVs derive power almost exclusively from Li-Ion batteries. Any advancement in this area closely follows the consumer electronics and power tool industries. Rechargeable Lithium Ion batteries have a wide military acceptance on small UGVs, and have been replacing the use of Lead Acid and Nickel Cadmium batteries. As a result of the switch to Lithium Ion batteries, mission duration and mission standby times for small UGVs have increased.

Power technologies for medium UGVs have largely been derived from the commercial engine markets and tend to use gasoline and/or ultra low sulfur diesel fuels. Medium sized UGVs will need to better align themselves logistically by adopting the battlefield jet propellant 8 (JP-8) fuel standard. This work includes the development of JP-8 fuel cells and internal combustion engines that are designed with reduced acoustic signatures, high operational efficiencies, high power density and improved reliability.

Advancements in power technologies for large UGVs also closely follow industry with the automotive industry being the primary influence. These advancements include the development of electric vehicles, hybrid vehicles, and increasingly efficient engines. At present, high-power energy storage devices (such as batteries and super capacitors) can propel a full-sized vehicle for up to forty miles. These technologies exist in production environments for automobile-sized vehicles.

Future Trends

In the near-term, Lithium-chemistry batteries will continue to experience incremental improvements in power and energy performance. In addition, fuel cells will enhance and reinforce battery usage and may eventually serve as a replacement for batteries on small UGVs. While current fuel cell technology for UGVs focuses on packaged fuels (such as propane), future technologies will enable the use of JP-8 fuel, reducing the Army's logistical burden. These technologies hold significant promise, but breakthrough advancements in power generation and storage technologies are unlikely in the short term. With the development and implementation of better power management technologies, UGVs will be able to increase the efficiency of existing power sources by a factor of 2x in some missions.

It is expected that cell and battery technologies will increase in power and energy density at the cell and battery system levels. Current lead acid systems are in the 30-50W-hr/kg range. Trends from Nickel-Cadmium to Nickel-Metal Hydride to Lithium-ion are extending the range from 45W-hr/kg to the 150 W-hr/kg range. It is expected that the targets for energy density will increase to ~400W-hr/kg over the next five to ten years with novel electrodes, electrolytes, and separators becoming available.

The S&T laboratories are expected to continue to leverage the automotive Electric Vehicle (hybrid, plug in hybrid) battery industry to support and drive military battery development. However, the DoD will likely have to lead efforts to Militarize emerging battery technologies to allow for

operation in extreme environmental conditions (i.e., to temperatures as low as -46°C and as high as +71°C).

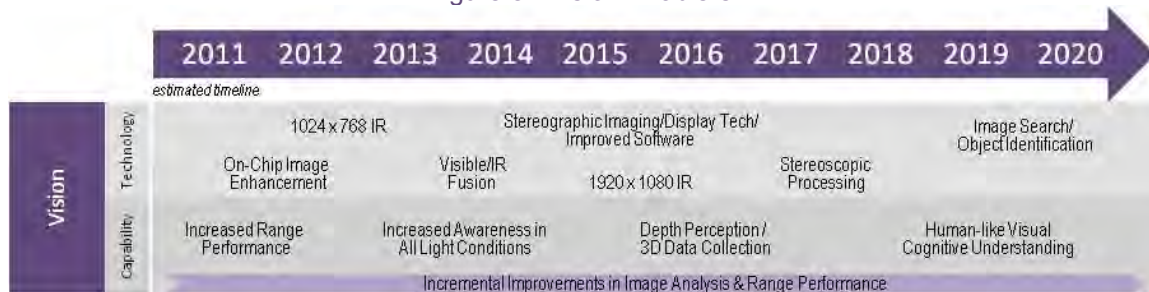
Government and industry labs will diverge on the development of engines based on JP-8 fuel. While industry will continue to develop more efficient gasoline and diesel fuel engines, the Army has adopted an overarching policy to transition all ground vehicles to JP-8 fuel.

The development of internal combustion engines and fuel cells for auxiliary power units for combat vehicles is expected to continue in the Army labs. Current technology has shown that internal combustion engines (ICEs) for robotic platforms are capable of operating on military JP-8/diesel fuel #2 (DF2) fuels for relatively short durations. The future expectations are to widen the operational temperature ranges and enhance the reliability for military applications. The trade-off between compact size and reliability in this class of engines will continue to be minimized. The acoustic signature of ICEs will continue to be reduced with the development of active noise control techniques.

Current fuel cell technologies are hydrogen based systems, which is not a battlefield acceptable fuel. In order to solve this issue, the labs are working to develop fuel reformers to allow fuel cells to be compatible with military fuels. Packaging a fuel reformer and a fuel cell into a confined space will continue to be a challenge. Over the next five to ten years, high power density engines and fuel cells will mature to the point of integration into UGVs to enhance near silent operation and allow for longer mission durations without refueling.

2.4 Vision

Figure 8. Vision Enablers



Description

Vision provided on ground robotics is comprised of the imaging sensor, lighting, optics, and the OCU display. Imaging sensors operate in one of following three spectrums:

Table 7. Vision Spectrums

Spectral Band	Description
Visible	Captures images visible to the human eye in full color
Near Infrared (NIR)	Captures images in low light for stealth operation and provides a monochrome or grayscale image
Thermal Infrared	Captures images without any light by responding to the latent heat radiated by all objects at temperatures above absolute zero

Visible and NIR imaging sensors use standard COTS silicon charged coupled device (CCD) or complimentary metal-oxide semiconductor (CMOS) technology, and are widely available at low cost. With selective filtering, the same sensor can provide both visible and NIR images. Lights

are generally included for additional illumination above ambient. Thermal imaging sensors use specialized focal plane arrays which respond to the longer wavelengths of thermal energy. While these systems are lower in resolution and much more expensive (7x to 10x) than their visible and NIR counterparts, thermal sensors provide the advantage of being able to see images obscured to visible sensor systems (such as in fog, smoke, dust, and complete darkness). Optics and lenses are used to focus the image onto the sensor and provide zoom capabilities for user adjustments to the field of view (FoV) and magnification of the image. Images acquired by the camera systems on the robot are compressed and sent over the data link to the OCU, where they can be viewed by the robot operator.

Status

Vision is a subject of significant research and development within both Government and Industry. Since 2009, the following activities have led to significant improvements in this technology:

Table 8. Vision Advancements

Major Activity	Type	Result
DARPA Challenges	Demonstration	Demonstrated obstacle detection and avoidance, visual odometry, lane detection, and sensor fusion
ARL Robotics CTA	Investigation	Investigated stereoscopic vision and terrain classification technologies
DARPA LAGR	Program	Matured vision-based navigation and learning technologies
SOURCE ATO	Program	Matures vision technologies that enable UGVs to safely operate within urban environments among humans, animals, and vehicles

UGVs are generally equipped with imaging systems that vary in resolution, range, and field of view. The following specifications are the imaging characteristics for what is typically found in fielded UGVs:

Table 9. Vision Specifications

	Visible	Infrared
Pixel Resolution	768 x 494	320 x 240
Field of View	40° H x 30° V	40° H x 30° V
Frame Rate	30 Hz, 60 Hz	15 Hz, 30 Hz
Detection Range	225 m to NATO Man Target	300 m to NATO Man Target
Zoom	3X to 26X	None

Numerous algorithms exist to improve the quality of information generated by imaging systems. On-chip color enhancement, contrast enhancement, image stabilization, and noise reduction are mature examples. Image sharpening and lens rectification algorithms will also mature very soon. Intelligent vision algorithms are the subject of intense research; but are not yet sufficiently mature to field. Such algorithms include object detection, recognition, and identification; object tracking and tagging; human intent analysis; visual odometry; sensor fusion; and terrain classification. Advancements in these technologies will likely reap significant benefits to UGVs.

Streaming video displayed on OCUs is typically degraded from the camera output due to the constraints of wireless data transmission. Digital images transmitted to the OCU over a wireless data link are often compressed because of radio bandwidth limitations. MPEG-4 (commonly used

by COTS UGVs) compression takes the video image and breaks it into smaller data packets that are broadcast individually over the air. If the radio signal is weak or noise is present, the data packets can be lost or corrupted, which results in latency and degraded images.

Future Trends

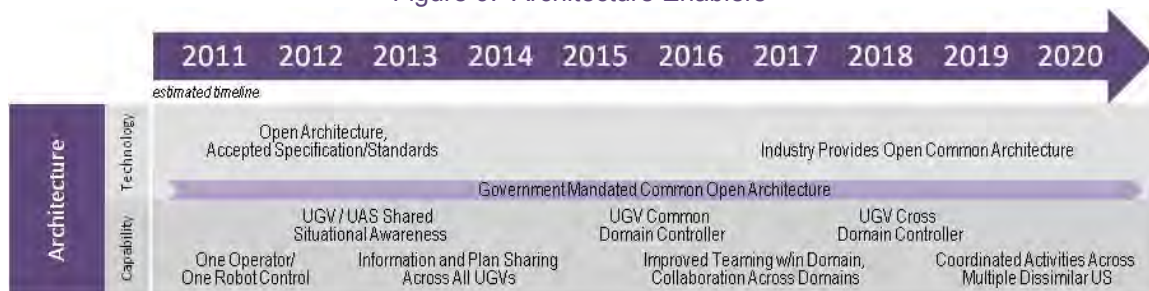
Improved imaging will be achieved with the integration of evolutionary technology developments mostly driven by the commercial and industrial sectors. H.264 advanced video encoding developed for Blu-Ray and other high definition video reduces the bit rate requirement for wireless transmission. This video compression methodology enables an increased number of pixels for more image detail or wider fields of view (including 360° images). With continued advancement and increased commonality of visible and infrared technologies, significant opportunities exist to fuse information from multiple spectral bands to increase situational awareness. Sensor fusion represents a major milestone in robotic vision that has broad application on both robots and manned platforms. The S&T community should accelerate investments in sensor fusion technologies.

In the mid-term, stereoscopic imaging technologies will enable UGVs to develop maps and detect obstacles in real-time. Such technologies are particularly useful in gripper control, as monocular imagers cannot effectively present depth information to enable delicate object manipulation. Stereoscopic technologies have also proven to increase situational awareness; and the S&T community will continue to investigate such technologies and their application to small robots. In addition, the S&T community needs to continue to develop technologies that increase dynamic range from imagers to increase awareness in all light conditions.

In the long-term, intelligent vision algorithms will likely experience tremendous improvements in capability. Many advanced algorithms in the coming years will continue to be developed for defense and security applications with mobile telephonic and commercial search applications driving the development. Opportunities exist to develop partnerships with the mobile telephonic and commercial search industries to leverage developments of these technologies. The S&T community needs to foster and mature these partnerships in research to develop and transition advanced robotic vision technologies to the field.

2.5 Architecture

Figure 9. Architecture Enablers



Description

A Systems Architecture describes the structure and behavior of a given system. It includes a functional description of hardware and software components as well as the interfaces between such components. An open architecture is one in which the interfaces are comprised of open standards, have no proprietary constraints, and enable the upgrading, swapping, and adding of components.

High-level UGV architecture includes, at a minimum, the following components and interfaces:

Table 10. Architecture Interfaces

Functional Components	Major Interfaces
Robotic Platform	Power Interface
Robotic Payload	Payload Physical and Message Interface
Data Transmission Link	Data Transmission Interface (frequency and waveform)
OCU	Human/Machine Interface (HMI)

The RS JPO owns and manages the Systems Architecture for Programs of Record whereas the OEM generally controls the COTS and NDI system architectures. Owning the systems architecture ensures the RS JPO is able to incorporate interoperability, control software/hardware modifications and upgrades for POR systems.

Status

Architecture is a subject of significant research and development within Government and Industry. Since 2009, the following activities have led to significant breakthroughs in this technology:

Table 11. Architecture Advancements

Major Activity	Type	Result
RS JPO Interoperability Effort	Interface Definition	A set of interface, messaging, and protocol requirements that will drive interoperability and modularity in all future RS JPO managed systems
MAGIC	Demonstration	Demonstrated autonomous coordination and teaming architectures in operationally relevant urban scenarios
AEODRS	Program	Modular architecture based on SAE AS5684 for Navy EOD robots
ACS, RIK, ROS, 4DRCS	System	A set of intelligent architectures for small-robot navigation
VICTORY	System	An architecture that enables C2 and interoperability on manned vehicles

At present, COTS robotic system manufacturers tend to maintain their own proprietary architecture. These manufacturers employ a variety of interface standards, including portions of the Society of Automotive Engineers (SAE) AS-4 family of standards (formerly Joint Architecture for Unmanned Systems [JAUS]) and Standardization Agreement (STANAG) 4586. These architectures are not managed by the RS JPO.

The RS JPO, in close collaboration with industry and other government agencies, is creating IOPs based on SAE AS-4 and other standards to enable disparate interfaces to communicate with one another. These IOPs define interoperability on platforms, payloads, communications, and controllers. As technologies mature, the RS JPO will add capabilities such as autonomy behaviors and other technologies to these IOPs. These profiles will assist APMs by providing direction in the acquisition of future UGV PORs, the upgrade of currently fielded systems, and the evaluation/acquisition of COTS components.

Future Trends

In general, robotic architectures currently focus upon individual UGVs, but over time, such architectures will likely tend toward multi-robot coordination and control applications. Initial applications of multi-robot coordination will be limited to a single domain, but are expected to expand across multiple domains and into manned-unmanned teams. Efforts to coordinate with friendly coalitions will likely occur in parallel. The TARDEC Coalition Warfare Project (CWP) (a proposed FY12-start) enables interoperability with Canadian robots based on the RS JPO developed IOPs and a similar North Atlantic Treaty Organization (NATO) effort. The CWP will allow for coordination across a broader coalition.

Communications technology advancements will help to enable multi-robot coordination. Multi-cast radios will likely improve this coordination and as such the S&T community should accelerate investments in multi-cast communication and other similar technology advancements. In general, technology development is not expected to be a major inhibitor to the adoption of multi-cast and other advanced technologies. Requirements must be developed and standard communications protocols must be agreed upon to enable advancements in multi-cast communications and multi-robot controls.

An anticipated UGV architecture requirement will be the requirement to interface with tactical and enterprise networks such GIG. ASA (ALT) has defined a strategy for realizing a Common Operating Environment (COE) network, into which UGVs are anticipated to interface. While achieving this interface would entail significant acquisition challenges in terms of information assurance planning, it would provide significant opportunities for increasing the capabilities of UGVs for Warfighters. For example, a Warfighter equipped with COE-connected mobile devices can search for applications that are needed to conduct the mission, to include UGV video feed and sensor-control applications. Additionally, geospatial models and other data structures available in the COE could aid significantly in enabling UGVs to optimally navigate autonomously. These types of operations could reduce the amount of computing power necessary on platforms and OCUs, and may reduce the wireless communication bandwidth required in UGV radios.

The Army will continue to increase coordination between ground and air domains. Although UAS and UGV systems are based on different standards (STANAG 4586 for large UAS and SAE AS-4/JAUS for UGVs), it is feasible for future systems to use an inward (ground) facing SAE AS-4/JAUS protocol and an outward (air) facing STANAG protocol to interoperate. STANAG 4586 is optimized for air system requirements and is highly reliable, but has a high latency format due to large message sizes. SAE AS-4 is optimized for UGV requirements with its somewhat degraded reliability, but low latency format for handling smaller message sizes. Additionally, as UGVs become more accepted and embedded in the force structure, interoperability with manned ground systems will be necessary. It is anticipated that Program Executive Office for Command, Control and Communications – Tactical's (PEO C3T) Vehicular Integration for C4ISR/EW Interoperability (VICTORY) standard will provide the interoperable interfaces for communicating with manned ground systems. RS JPO's interoperability profiles will eventually need to define the protocols for interfacing with VICTORY-based systems

2.6 Soldier-Machine Interface (SMI)

Figure 10. Soldier Machine Interface Enablers



Description

Soldier Machine Interfaces (SMI) are the physical devices (primarily operating controls and video displays) that give Soldiers the ability to perform their mission in a safe and effective manner. SMIs enable the operator and UGVs to interact with one another. SMIs allow soldiers to both control and acquire situational awareness from UGVs. These interfaces have to be usable and visible in all the environmental conditions that the Soldier will face while in combat. Soldier machine interface programs have shown to improve soldier performance through the use of automations and more intuitive screen design.

Future developments in the area of soldier machine interface will have to address simultaneous task completion and interoperability standards for common icons, graphics, alerts and controls and other areas.

Status

SMI is a subject of strong research and development in both government and industry labs. Currently the number of tasks that the soldier has to perform while on a mission is increasing, providing more stress and mental workload in complex environments. It is very difficult for the soldier to operate multiple controls and be able to process information on multiple screens. Programs are currently under development to help reduce the mental and physical strain that the soldier has to go through while performing essential mission tasks. Since 2009 the following activities have led to incremental improvements in this technology:

Table 12. Soldier Machine Interface Advancements

Major Activity	Type	Result
ARL HRED CAN CTA	Investigation	Investigates neuro-ergonomics for mounted and dismounted Soldiers
HRI ATO	Program	Matured indirect vision driving and mobility aids
IMOPAT ATO	Program	Matures situational awareness and indirect vision driving technologies
SPAWAR MOCU	System	An unmanned vehicle and sensor operator control unit for Navy robots

RDECOM has also developed advanced control aids such as point-and-click destination setting, path projection, high-level command interfaces, and sensor slew-to-cue to improve semi-autonomous operation with UGVs. The S&T community is also developing mitigation technologies to overcome latency in control and video acquisition. In the future, such technologies will enable SMIs to simultaneously control multiple UGVs in coordinated operations.

Numerous ongoing programs focus on the need to develop one controller that performs numerous tasks on a UGV. This eases the mental strain caused by performing different operations with dissimilar controllers. A single controller enables the Soldier to control and observe more than one dissimilar unmanned ground vehicle with the same interface display and control function mapping. The High Definition Cognition ATO (TARDEC and Army Research Laboratory [ARL] joint ATO) works to monitor the state of the Soldier in an operational environment to help make the crew station adaptable to the Soldier to increase operational efficiency.

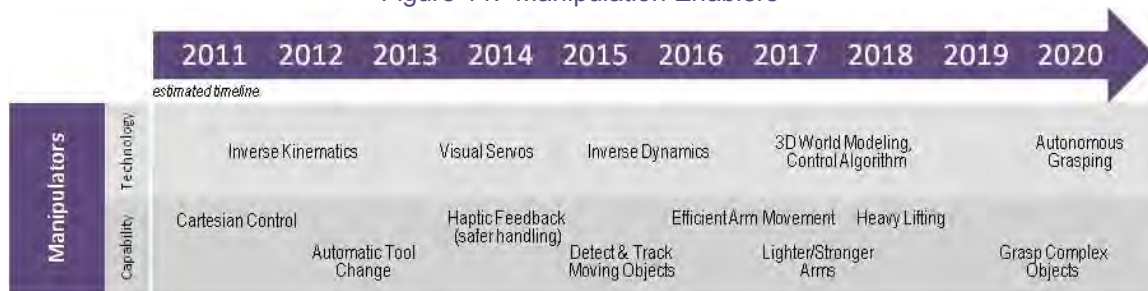
Future Trends

Gamepads have often been used to operate UGVs but in recent years the S&T community has shifted its SMI development efforts toward touch-screen displays. The touch-screen displays enable Soldiers to both control and receive video information from their robots. SMIs will likely be developed for mounted touch-screen displays before dismounted and flexible displays are developed. The future of SMI also includes the continued development and refinement of voice control/recognition systems, advanced reconfigurable head up displays, 3D displays and other general display technologies. Haptic controls for enhanced perception to what the robot is doing and experiencing will become available and integrated into the SMI. These controls take advantage of the users' sense of touch by applying forces, vibrations and/or motions to the user as a feedback mechanism.

Advanced neuero-ergonomic technology and techniques will allow for driver brainwave, heart rate and eye tracking monitoring. The Brain Computer Interaction Technologies (BCIT) ATO (joint TARDEC/ARL ATO, FY13 start) will develop technologies which will enable soldier performance prediction by using advanced algorithms to monitor a soldier's brain signal for indicators of performance state degradation over time. BCIT ATO also will develop technologies that have adaptive tutoring, which will monitor brain signals to detect states associated with lack of learning and automatically adjust training strategies to best match soldier states. Text to speech conversion systems will allow soldiers the ability to select different languages and voices (i.e., male/female) to operate different controls, or send different messages. The S&T community needs to continue to develop networked controllers that use standard message sets to send information over radio. Such controllers use both military and low-cost commercial hardware to provide a flexible, reliable, and secure communications and control framework. These controllers enable dismount soldiers to more effectively interact with robots in a dynamic operational environment. Creative interoperability techniques and technologies will allow soldiers to operate both unmanned aerial vehicles and unmanned ground vehicles using one controller.

2.7 Manipulation

Figure 11. Manipulation Enablers



Description

Manipulation technologies enable robots to lift and reposition objects of various sizes or shapes. UGVs within a military context must generally conduct manipulations on objects that are unique and yet to be encountered.

Advancements in manipulation typically focus upon manipulator hardware and controls. Significant efforts are applied to design end-effectors such as grippers, claws, and shovels that enable successful manipulation with multiple joints and force feedback capabilities. Manipulators may also exhibit semi-autonomous behaviors to assist the operators during critical operations.

Status

Manipulation is a subject of strong research and development within both Government and Industry. Since 2009, the following activities have led to incremental improvements in this technology:

Table 13. Manipulation Advancements

Major Activity	Type	Result
ARL Robotics CTA	Investigation	Investigated actuation techniques, intelligent gripping, and coordinated manipulation
AEODRS	Program	Matures autonomous manipulation for Navy EOD
DARPA ARM	Program	Matures autonomous arm control and gripping capabilities

Robotic manipulation currently exists in the form of robotic forklifts, front end loaders, specialized platform toolkits, and manipulator arms. Most of the currently fielded manipulators are controlled by operators who move each joint manually and independently. Many of these joints are powered by electric motors, however hydraulic and pneumatic actuators have been utilized. The systems are primarily employed for moving/displacing, lifting, and placing objects, as well as turning door knobs, operating tools and assisting in platform mobility. Most manipulation is currently limited to small EOD and engineering platforms. These manipulators can also utilize small, simple tools designed for use with specific systems.

Additional DoD and industry efforts are focusing on the development of rapidly interchangeable end-effectors with hydraulic force feedback capabilities and complex manipulation capabilities.

Future Trends

Future technology developments, both near and long term, will greatly enhance manipulation capabilities. Inverse kinematics will allow the operator to provide the desired location of the end effector, while having the robot move the joints (rotation and translation) to reach the desired end state. This capability will allow Cartesian control (fly-the-end-effector) of the manipulator. Fly-the-end-effector technology is widely used by robots in industrial applications where the additional sensors and processing power are more readily available. Experiments have successfully demonstrated this capability on robots, with some new software packages (Aware 2 PackBot) implementing “fly-the-camera.” In addition, this technology is directly related to pre-defined poses and the ability to perform automatic tool change.

Visual servoing is a technique using feedback from visual sensors (cameras, light detection and ranging [LIDAR]) to control features of the robot. This technique monitors and adjusts based on the image, and not the manipulator’s location. This methodology allows for variation in the manipulator hardware and grasping technology without it affecting the end placement. This capability will enable semi-autonomous control by allowing the robot to make adjustments based on the desired outcome.

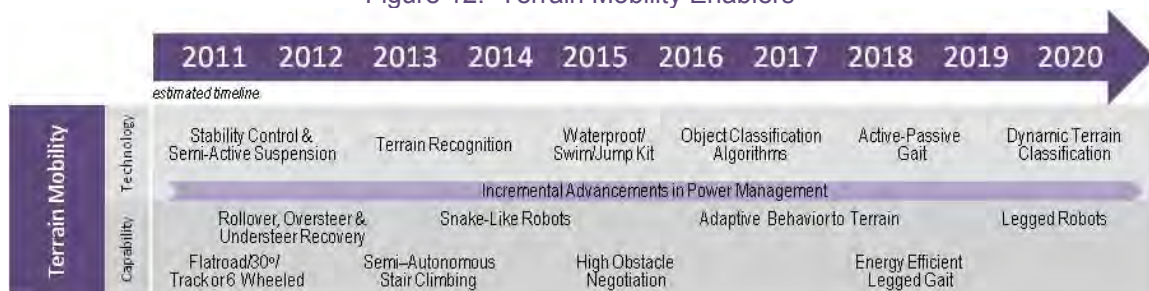
Haptic feedback provides additional information to the operator based on the sense of touch and feel carried out through the controller. As an example, haptics can give an indication of the weight or firmness of an object. By providing additional information to the operator, finer grasper control and a better understanding of the items being manipulated can be achieved. Haptic feedback is becoming commonplace in Industry and is widely used in game controllers, cell phones and medical environments.

Inverse dynamics involve knowing the desired movement, and calculating the correct forces required to generate that movement. Whereas inverse kinematics calculate the geometry (angles, distances), inverse dynamics calculate the forces, velocities, and accelerations to travel a desired path. This calculation can be quite complex, as manipulator weight, object weight, and even robot orientation with respect to gravity can have an effect on the forces required. As the size of the manipulator and load increase, and the speed of the manipulator increases, inverse dynamics become more important. Several large industrial robots currently use inverse dynamics in their control methodologies. However, their operating environments are much more stable and they have access to more computing power. As computing power and sensors increase, the ability to add inverse dynamics to robotic systems will also increase.

As the robot is able to build a more advanced 3D model of the world, the manipulator's ability to autonomously move and grasp will increase. The use of multiple manipulators on a single platform will also be possible though coordination in the 3D model. Additionally, advances in physical components and control algorithms will increase the ability of the manipulators in an attempt to approach human-like motion. There are several laboratory experiments that show this is possible, and provide manipulator teams a direction for the future.

2.8 Terrain Mobility

Figure 12. Terrain Mobility Enablers



Description

Terrain Mobility enables robots to negotiate difficult terrains and obstacles. Such terrains and obstacles include:

Table 14. Terrain Mobility Terrain and Obstacles

Terrains	Obstacles
Paved roads, dirt roads	Curbs, potholes, puddles
Grass, brush, rocks	Ditches, bushes, rocks
Sand, shallow water	Stairs

UGVs typically use tracks and wheels to enable mobility. In general, tracked and wheeled robots utilize the following control systems:

Table 15. Terrain Mobility Control Systems

Control System	Description
Ackermann steering	Used in automobiles to steer inside front wheels more than outside front wheels
Skid steering	Used in tracked and wheeled systems to spin in place
Omni-directional steering	Used in robots to spin in place with less degradation to wheels

Technologies such as semi-active suspension, stability control, and integrated vehicle dynamics enhance terrain mobility characteristics for UGVs.

Status

Terrain mobility is a subject of significant research and development within both Government and Industry. Since 2009, the following activities have led to significant breakthroughs in this technology:

Table 16. Terrain Mobility Advancements

Major Activity	Type	Result
ARL MAST CTA	Investigation	Investigated ground maneuverability and mode transitions
ARL Robotics CTA	Investigation	Investigated terrain representation and multimodal locomotion.
UGCV	Program	Matured intrinsic mobility capabilities through irregular terrains
S-MET	Program	Matures payload carrying and dismount following capabilities
DARPA LS3	System	A legged robot with improved mobility over irregular terrain
SMSS	System	A six-wheeled robot that carries payloads and follows dismounts
Crusher, APD	System	A set of six-wheeled robots with intrinsic mobility in irregular terrains

In general, the smallest available robots travel on wheels, and they typically ride in urban or indoor environments upon smooth surfaces. Most small robots use tracks to improve off-road mobility and obstacle negotiation. Large UGVs tend to employ wheeled and tracked skid-steer systems; but add-on autonomy kits have been integrated on manned vehicle platforms that employ Ackermann steering technologies. Basic controls for these technologies are highly mature; but relatively new technologies such as semi-active suspension and stability control enable UGVs to ride upon more difficult terrains at higher speeds.

Legged robots have continued to improve through research. The DARPA Legged Squad Support System (LS3) robot is the leading system for legged mobility; and two legged systems will be available for evaluation in June 2012. The LS3 is approximately 400 pounds; and it supports twenty-four hour missions on a broad set of difficult terrains. The LS3 robot contains four legs; but several research projects have also begun to examine bipedal locomotion. In addition, snake-like robots have been developed to attain mobility in niche environments such as sewers or culverts. These snake-like robots have been used on several occasions during disaster relief operations.

Future Trends

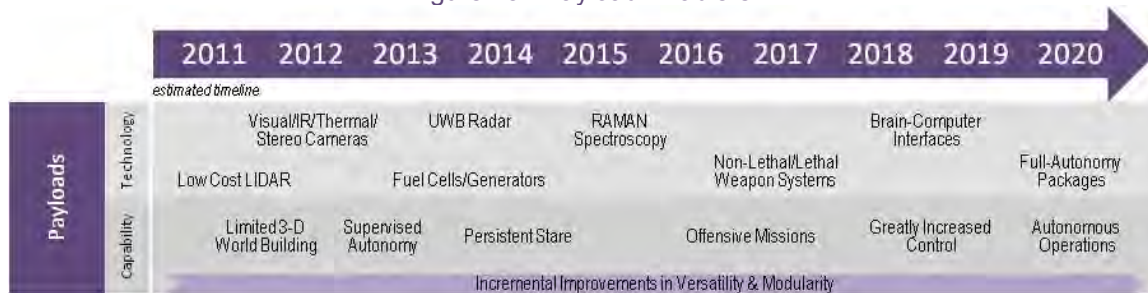
Tracked and wheeled mobility will continue to dominate the robotics trade space for many years. Legged mobility will likely remain in research for much of the coming decade; but once matured, these systems may radically increase mobility in relation to current platforms. Such robots will likely have wide application on future battlefields. Snake robots will likely remain suitable for only niche environments and are not envisioned to be widely employed in combat situations.

Dynamic balancing algorithms are fairly mature, but significant research will be required to mature efficient gaits (i.e., the robots' walking style). At present, most legged robots maintain active gaits; but living creatures typically possess active-passive gaits to improve efficiency. Since legged robots require large amounts of energy to operate, innovation in power technologies will be required to fully mature legged robots. As such, the S&T Community should continue efforts to develop effective power management technologies.

Modern platforms exhibit sufficient mobility to conduct next-generation autonomous applications, including leader-follower operations within convoys and semi-autonomous control of small robots in urban environments. As a result, continued advancements in fielded mobility will likely arise from developments in terrain and obstacle recognition. Such technologies enable the robot to adapt its parameters to improve mobility performance in both autonomous off-road applications and following dismount. As such, the S&T Community should continue efforts to apply advanced terrain and obstacle recognition algorithms that improve mobility on current platforms.

2.9 Payloads

Figure 13. Payload Enablers



Description

Payloads may be considered from the point of view of the message communication, network access, operational, or functional frameworks. The message communication framework allows for payloads to be defined as to whether they receive defined messages or raw inputs. The network access framework defines payloads on the basis of their ability to be accessed via the network (either Open or Closed). The operational framework defines payloads as internal system payloads (fuel and temperature sensors), external operational payloads (cameras, LIDARs, etc) and add-on mission modules payloads (chemical, biological, radiological and nuclear [CBRN] sensors, etc). The functional framework approaches payload definitions from their interactions with the environment; they are classified as sensors, emitters, or actuators. For the purposes of this Roadmap, payloads are discussed from the „functional“ point of view. The Interoperability WIPT will continue to research, develop and review payload definitions as UGV technologies continue to mature. Special consideration on how to characterize batteries and other power sources, as well as control mechanisms is still under development and expected to be defined in the near future. Robotic payloads are categorized as follows:

Table 17. Payload Types

Payload Type	Description
Sensors	Any equipment that gathers information from the environment
Emitters	Any equipment that interacts with environment by leaving host platform
Actuators	Any equipment, powered or unpowered, that interacts with the environment without leaving host platform

The following table provides examples of Sensors, Emitters, and Actuators:

Table 18. Payload Examples

Sensors	Emitters	Actuators
Visual Sensors	Obscurant producers	Manipulator arms and Grippers
Ranging Sensors	Counter-IED systems	Track flippers and flippers
Acoustic Sensors	Lethal/Non-lethal systems	Push and pull attachments

Demands for increased capabilities on UGVs will require the development of robust and versatile robotic payloads. As such, robotic payloads must be developed with versatility and modularity in mind.

Status

Nearly all fielded robots include a sensor to enable driving and navigation. Visual sensors (day-time color, near infrared, and thermal infrared systems) are now often required for standard robotic missions, such as EOD, personnel or vehicle inspection, and route clearance. Ranging sensors (LIDAR, radio detection and ranging [RADAR], and sound navigation and ranging [SONAR]) have been integrated onto many robots to support autonomy and ISR. RDECOM is intently focused upon efforts to fuse information from visual and ranging sensors to improve robotic world models and increase situational awareness. RDECOM is also developing additional payloads (ground-penetrating RADARs and spectroscopic sensors) to detect buried command wires and IEDs.

Many currently fielded UGVs are (or may be) equipped with emitters in the form of lights, speakers, obscurant producers, and CREW systems. RDECOM has been developing lethal and non-lethal payloads for a number of years. Several prototype systems have been developed that are capable of deploying a lethal and non-lethal capability. These include the use of M240/M249 machine guns, as well as the Anti-Personnel Obstacle Breaching System and Venom V-10 systems.

Manipulator arms, grippers and pan/tilt mechanisms have become common payloads on most fielded UGVs. Additional advancements have been made in the development of push and pull attachments. These include the development and fielding of the Tangle Foot kit, various rollers and plow attachments. The RDECOM-developed Tangle Foot kit is a low-cost, purely mechanical counter-tripwire system consisting of a rake device pulled behind a UGV, and a fiberglass pole attached to the body of the robot. RDECOM and the REF are working to develop and assess mechanical roller devices for several small to medium class systems. Actuators have also been developed to enhance increase SA. One example is the Situational Awareness Mast (SAM). The SAM is a collapsible/expandable 8' long triangular-shaped metal mast with internally threaded electrical cables to allow for an antenna or camera to be mounted to the top of the mast. This actuator may provide a much higher field of view of its surrounding (if camera is installed on SAM). The SAM was successfully incorporated into the Omni Directional Inspection System (ODIS) UGV.

Future Trends

As UGV missions continue to expand, the requirements placed on UGVs will constantly rise. There is an ongoing push to increase UGV autonomy, with a current goal of “supervised autonomy,” but with an ultimate goal of full autonomy. These requirements necessitate the continual development of more advanced sensor UGV payloads. Future payloads must be cognizant of the platform’s size, weight and power constraints as well as overall system practicality and usability.

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Payloads must be versatile and modular to extend the mission capacity of host platforms. Such payloads must support the use of common physical and software interfaces. As such, the S&T Community should continue to define interoperable interfaces; and, it should continue to include additional payload connection ports to further increase modularity.

The development and incorporation of a lethal capability has been demonstrated on numerous systems; however, the safety and political ramifications of lethal systems has not been fully addressed and resolved.

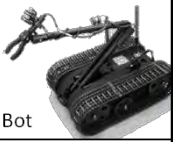
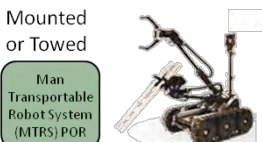
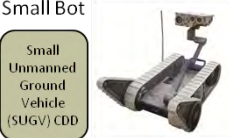
Chapter 3: UGV Modernization Strategy

3.1 Army UGV Campaign Plan

TRADOC and unmanned system users recognized a need for an overarching strategy to aid in the development of future unmanned assets. As a result, the Army Unmanned Systems (Air, Ground, Maritime) ICD (2010-2035) was approved November 2009, providing a single over-arching strategy for modular, interoperable, coordinating, and collaborating unmanned systems across the Warfighting Functions. The first effort undertaken since the approval of the ICD was to develop an Unmanned Ground Vehicle Campaign Plan. The U.S. Army UGV Campaign Plan provides a strategy to guide UGV developments and employment as described in Figure 14, Army UGV Campaign Plan, while offering enhanced soldier protection from conventional and non-conventional threats. The Army UGV Campaign Plan:

- Supports the full spectrum of military operations through a UGV Class of Vehicles (CoV) concept with mission module payloads enabled by non-proprietary open architecture standards
- Has UGV CoV deployed over a 25-year time frame divided into near-term, mid-term, and far-term
- Evolves and integrates today's specialized UGVs into a UGV CoV enhancing effectiveness and efficiencies
- Calls for the continued evolution from tele-operation to semi-autonomous (near- and mid-term) to collaborative unmanned system warfare (far term).

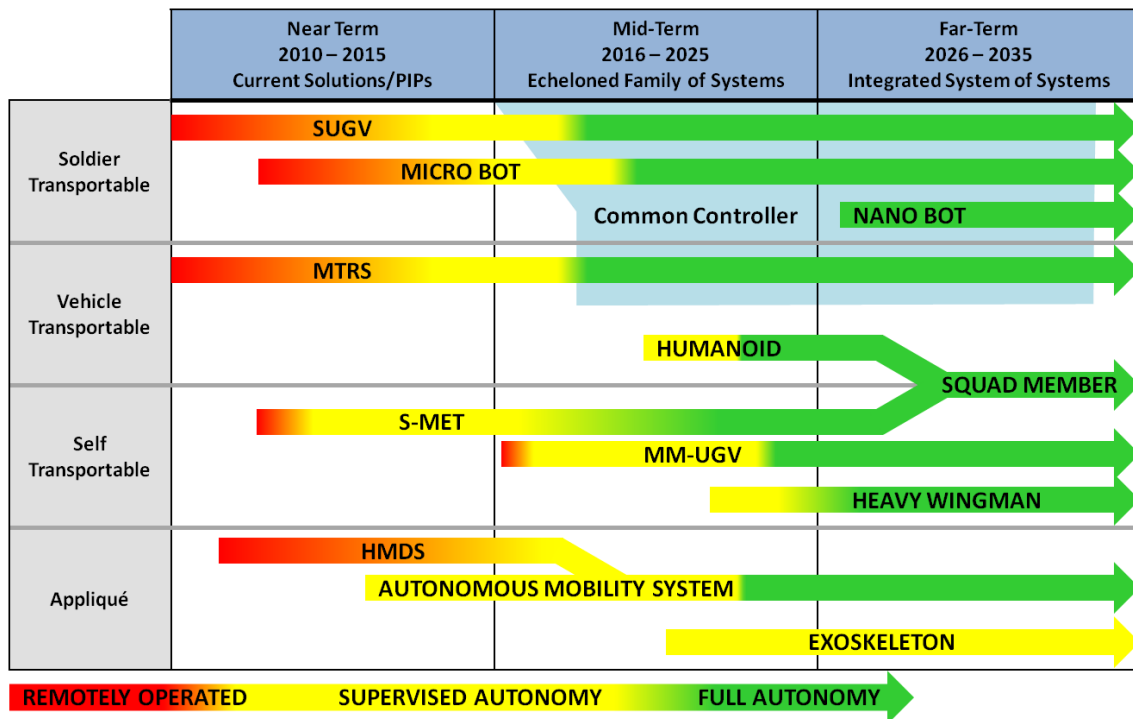
Figure 14. Army UGV Campaign Plan

Soldier Transportable	Vehicle Transportable	Self Transportable	Appliqué
 Crew Served Bot	 Mounted or Towed Man Transportable Robot System (MTRS) POR	 Soldier Follower – IBCT Squad Mission Equipment Transport (SMET) CDD	 Remote Operation Husky Mounted Detection System (HMDS) POR
 Small Bot Small Unmanned Ground Vehicle (SUGV) CDD	 Medium Wingman – SBCT Multi-Mission Unmanned Ground Vehicle (MM-UGV) CDD	 Heavy Wingman – HBCT	 Supervised Autonomy Convoy Active Safety Technology (CAST) CDD
 Micro Bot	 Armed Battlefield Extraction Assist Robot (BEAR) Initiative	 Squad Member	 Full Autonomy Combat Autonomous Mobility System (CAMS) JCTD
 Nano Bot	 Humanoid Battlefield Extraction Assist Robot (BEAR) Initiative	 Squad Member	 Exoskeleton Exoskeleton (XOS) CDD

On the following page, Figure 15, Army Capability Timeline, identifies the U.S. Army UGV capability timeline supported by the UGV Campaign Plan.

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Figure 15. Army Capability Timeline



The ICD and Campaign Plan are defined by the four robotic areas described below.

- 1. Soldier Transportable CoV.** The soldier transportable CoV is defined as a UGV system with weight not exceeding 35 pounds and with forms that allow them to be carried by Soldiers or Marines for extended periods of time over varying terrains. Examples are the SUGV and Mini-EOD discussed in Appendix A. Crew served platforms weighing more than 35 pounds may also be included in this class of vehicles. The majority of soldier transportable systems are used for surveillance, reconnaissance missions, and standoff IED detection and defeat. Requirements for soldier transportable systems are expected to call for smaller, lighter, more capable systems with longer endurance and a common controller. Future capabilities for this CoV will include throwable and microbot systems. Throwable and microbot systems may be further defined by reduced size and weight and used for around-the-corner, building and room ISR, and silent watch missions. Continued advancements in antenna design, autonomy, miniaturization, power sources, and control mechanisms are required in order for these capabilities to be fully realized. The main barriers currently facing soldier transportable systems are the absence of a common compact controller and the development of an architectural framework that will permit a high degree of autonomy.
- 2. Vehicle Transportable CoV.** Vehicle transportable unmanned systems are heavier and require a prime mover for transportation to and from a mission. Currently fielded examples of vehicle transportable systems in the RS JPO inventory include the TALON, PackBot, MARCbot, and the M160. The M160 is used for mine neutralization and area clearance, whereas the TALON is employed for IED detection, defeat and route clearance missions. Future requirements for vehicle transportable systems are expected to include more advanced, reliable and autonomous area and route clearance robotic vehicles as well as humanoid like systems. Continued advancements in autonomy (to include intelligence understanding and decision making), power systems, and enhanced mine detection and neutralization techniques and methods are needed. Some of the barriers facing the

vehicle transportable class of vehicles include improved mine detection and neutralization, enhanced autonomy, intelligence understanding, and decision making

3. **Self Transportable CoV.** Self transportable systems are, by definition, systems that can move under their own power, up to road march speeds, without assistance from a prime mover or other sources. Self transportable systems are not manned systems with appliqué kits applied, rather they are systems that have been developed explicitly as unmanned vehicles. Self transportable systems are envisioned to provide a wide range of capabilities to the Warfighter. These capabilities may include the advent of a robotic wingman, the continued development of mine detection and neutralization platforms, as well as vehicles to serve as robotic „mules“ (Common Mobility Platform) to take on multiple soldiers' loads. Continued advancements in autonomy, sensors and sensor fusion are required in order for these capabilities to be realized. Multiple experiments and demonstrations are currently being developed to demonstrate capabilities for self transportable systems. These events will serve as risk reduction efforts and will help provide direction to the S&T communities. The main barriers currently facing self transportable systems are increasing the level of autonomy, terrain mobility, obstacle detection and recognition at tactical speeds
4. **Appliqué CoV.** The Appliqué COVs are systems that can be used to convert fielded and future manned systems into unmanned systems. This class may also include the future development of exoskeleton systems that will serve to enhance an individual soldier's inherent, natural capabilities. These systems are envisioned as „kits“ that include all the hardware (sensors, cables, actuators, control station, etc.) and software required to fully operate and monitor the selected vehicle remotely. Current systems under development that fall into this CoV include the ANS, SANDI, and Autonomous Mine Detection System (AMDS). Candidate vehicle systems for kit development cover the entire range of current and future Army and Marine Corps vehicle fleets and include small forklifts, High Mobility Multipurpose Wheeled Vehicles (HMMWVs), Family of Medium Tactical Vehicles (FMTVs), Huskys and Mine Resistant Ambush Protected (MRAP) vehicles. The appliqué kits can be used to project the force forward as well as removing the Soldiers and Marines from some of the dull, dirty and dangerous missions. These systems will be initially used for convoy, C-IED, and ISR missions. Key advancements are required in the areas of autonomy, processing, size, weight and power (SWaP), sensor development, and sensor fusion for this CoV to be fully matured. Additional barriers to appliqué systems will be safety and soldier acceptance

3.2 RS JPO Technology Needs Analysis

The RS JPO has conducted a Technology Needs Analysis to support meeting the goals outlined in the UGS Campaign Plan as a way to help focus Government labs, Industry and academia S&T research efforts. The list of needs, identified in Table 19, is prioritized according to what technology growth is needed to meet future capability requirements for CoV identified in the Campaign Plan. The list of operational needs was developed using requirements from robotic CDDs, CPDs, JUONS/ONS documents as well as the Unmanned Ground Systems ICD. The list is intended to give S&T labs direction on where RDT&E funding could be best invested. Additionally, in the case where funding is in jeopardy, the Needs Analysis potentially provides S&T labs a technology transfer path to justify their program budget.

The Needs Analysis includes some technologies that are already being developed by Government or Industry. Each of the technology needs may include near, mid and far term development goals. During the development of these technologies, S&T communities should be mindful of the size, weight and power impacts to surrogate vehicles as well as the individual ground robotic systems. Across all the robotic technology development efforts, S&T labs should strive to obtain Government Purpose Rights on all software code, as well as collaborate with the ground robotics test

community on test procedures and safety requirements to increase their familiarity with autonomous ground robotic systems.

Table 19. Technology Needs

Priority	Technology Area	Technology Needs
1	Autonomy	Looking for improvements in the various levels of autonomy from semi-autonomous, supervised and fully autonomous capabilities. The capability is needed in area clearance, route clearance (marks and detects), convoy, soldier-follower, manned/unmanned teaming, situational awareness and navigation in a GPS denied environment. Also for route detection, planning, and maneuver capabilities over soldier passable terrain.
1	Obstacle detection and Avoidance	Paired with autonomy in that sensors and methods of control are necessary to detect and identify obstacles and manage navigation across soldier passable terrain, and vehicle routes, i.e., convoy.
2	Interoperability	Hardware and software interfaces IAW RS JPO interoperability profiles; capable of integrating payload modules without interfering with other existing components (plug-and-play).
2	Commonality	The appliqué kits for converting tactical wheeled vehicles into robotic platforms must include a "Kit A" and "Kit B". The Kit A is the brains and should be common across the fleet. The Kit B is platform specific and may include such things as sensors, camera's, GPS and IR lights and actuators.
3	Increased NLOS and LOS capability (COMS)	Reliable capability is needed to extend LOS and NLOS control especially in complex/urban terrain, culverts, and underground. Capability must be able to provide extended network and communication capability.
3	Improved Culvert Inter-rogation Ability	The capability for robots to operate in the subterranean level, in culverts 24 inches in diameter, and for extended distances is needed. The capability could be used with tether, autonomy, radio relays, or other technologies.
4	Frequency Spectrum Adaptability	Frequency Spectrum Adaptability – The frequency range of the UGV emitters must be flexible enough to adapt to changes in DoD and non-DoD frequency spectrum allocations, as well as being capable of being used in civilian bands, both in the continental U.S. and overseas. Additionally, multiple UGVs must be capable of operating in the same area without degradation of control or operational effectiveness. Must be CREW compatible.
5	Extended Mission Duration	Capability is required to extend the various missions of UGVs. Robots must be capable of providing persistent stare capability for extended mission durations. Robots must operate in increasing range and mission duration while reducing impact to the Soldier's burden. Continuous operation for 7-24 hours without recharging power supplies is desired. This does not necessarily mean extended battery life; the capability could be achieved through other means.
6	COMSEC Encryption Capability	Robots must possess embedded capability to encrypt/decrypt or encode/decode using approved techniques with existing COMSEC equipment up to experimental techniques applicable to NSA certification criteria.
6	Net-Ready KPP	Robots must be able to enter and be managed in the network, and exchange data in a secure manner to enhance mission effectiveness.

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Priority	Technology Area	Technology Needs
7	Common Controller	This capability need varies from a controller capable of controlling four or more UxVs to a controller capable of controlling numerous plug-and-play payloads. Any controller needs to be lightweight, and readable in full direct sunlight and moon-less night (with night vision goggles).
8	Improved Optics	Capability needed for sensors systems that allow faster detection in all lighting conditions (including those with limited visibility such as dust, rain, and fog) at increased standoff distances, with lower detection error rates.
9	Health Management System	Capability to utilize Condition Based Maintenance Plus; HMS will provide information for the logistics Common Operating Picture to assist commanders with forecasting supply requirements, combat power, and maintenance needs. Current robots do not include this capability.
10	Render Useless Mechanism	The capability is needed for a render-useless mechanism that can be initiated from a distant control source.
11	Layered, Escalating Defense Mechanisms	Capability needed for non-lethal intrusion prevention, and layered, escalating self defense capability.
12	Audio Directional Detection	Sensors systems needed that allow faster detection at increased standoff range, with lower detection error rates and increased mission duration (improvement on current capability).
13	Explosive Detection	Capability needed for a modular (plug-and-play) capability to detect explosive hazards IAW explosives library.
14	Embedded Training Capability	Capability for platform specific individual (operator/maintainer) tasks within live, virtual, and constructive environments with collective training capability (up to Battalion level) for FSO- mission essential tasks within live, virtual and constructive environments.
15	Location Reporting	Capability needed to provide platform location as a distance and direction reading from the operator's position with greater accuracy showing direction of movement, and sensor orientation to the operator.
16	Integrated Tool Kit	Capability to utilize an integrated tool kit is needed. Manipulator arm selects tool for end-effector.
17	Dismounted Mission Enabling Robotics	Capability to enable robots as co-combatants with increased intelligence and durability.

3.3 RS JPO Priorities

As the RS JPO pushes forward to meet the robotic needs of the Warfighter, we recognize the need to modernize and enhance fielded robotic systems. Currently, the RS JPO manages systems that are in all phases of the acquisition life cycle, bringing rise to many unique opportunities and challenges. Sustaining and improving the currently fielded fleet is one of our top priorities. Along with this stated priority is the application of lessons learned to emerging POR to ensure today's shortfalls are addressed in tomorrow's materiel solutions. Overarching all of these goals is the

duty to provide unmanned ground systems that are multi-mission, have modular payloads, and are able to work within a teaming environment. To achieve these goals, the RS JPO is leveraging both internal and external talents through established working relationships with all four Services' technology bases and by identifying near, mid and long term needs for UGVs.

3.3.1 Modernization

Fleet management and modernization are critical for UGS as shrinking defense budgets will reduce the number of approved and resourced robotic capability documents. Leveraging currently fielded systems through modernization will allow for the Warfighter's needs to be addressed as new robotic systems are brought online through the CDD and CPD process.

Numerous improvement efforts have been developed and are currently underway across the fleet of RS JPO fielded systems. Many of the systems in the field are early 21st century designs with software and payloads that feature 10 year old technologies. Sustainment of these systems has revealed some instances where a slight change in the design or the addition of a part can drastically reduce failures. As an example, the PackBot system was experiencing inoperable payloads as a result of bent payload pins. By working with the OEM, the Payload Pin Alignment Insert (a plastic insert) was developed to protect against pins bending when payloads were reinstalled. This system modification has been issued to the field with positive feedback.

The RS JPO maintains a consistent strategy to leverage fielded systems to the maximum extent possible. Limited software and hardware upgrades are being applied to systems like the TALON 3B and PackBot 510 to provide more modernized and enhanced capabilities. As mission needs change, the strategy is to further enhance systems capabilities by the addition of improved payloads and optics. The following paragraphs provide an overview of the short term improvement/modernization plans for several of the currently fielded systems.

PackBot Modernization

Multiple variants of the PackBot have been fielded, including the PackBot 500 EOD, PackBot 500 FIDO, and PackBot 510 FasTac. Modernization of the fleet is underway to baseline the configuration to a common platform with plug-and-play payload variants based upon mission requirements. The common platform will be a FasTac 510 with Aware 2 software. Aware 2 provides resolved motion, preset poses, improved graphic user interface (GUI), snapshot to memory, and enables the plug-and-play modularity of multiple different payloads configured for the PackBot chassis. Phase I of this upgrade includes:

- 500 series robots (FIDO and EOD) will be upgraded to the 510 chassis and Amrel OCU, keeping the existing three link arm, FIDO sensor (if equipped), tracked flippers, and shipping case,
- Existing FasTac robots will also be upgraded to Aware 2. The FasTac payloads (Camera Arm Manipulator [CAM], Short Arm Manipulator [SAM], and untracked flippers) will be retained with the robot,
- Additional payloads will be procured for the upgraded FasTac, and optionally provided according to the mission requirements
 - The 510-series three link arm (Manipulator 1.0) in shipping case
 - Enhanced Awareness Package payload provides a wide angle driving camera with light emitting diode (LED) lighting and a speaker/microphone
 - Tracked flippers.

Future modernization of the platform will be pursued with incremental development and fielding of modular payloads compatible across the platform. Capabilities being considered include:

- COFDM radio for improved LOS/NLOS range

- Wide Angle Robotic Vehicle Vision System (WARVVS) camera for super wide angle video imaging (180o FoV)
- Thermal camera for use at night, in fog, or in dust
- User Assist Package (UAP) for the following user assist behavior
 - Retrotraverse (on command and loss of comms)
 - Self-righting
 - Global Positioning System (GPS) mapping with Auto-Trak
 - Gripper Force Feedback
- Taller antenna on robot chassis for improved radio range
- Improved lighting for long distance viewing at night

Features being considered for a future block upgrade to the software include:

- Ad hoc Mobile Mesh Network with radio repeaters
- Improved video compression and network drivers for enhanced video
- Embedded reliability functions, including a one-hour meter for all processor-controlled payloads and on-board prognostics
- OCU-Initiated calibration of all payloads

MARCBot Modernization

The MARCBot has been fielded since 2004, with 850 robots deployed. In 2008, the system was upgraded to replace the control and video radios with a single digital radio at a higher frequency (due to the jamming frequencies when used OCONUS). The custom suitcase controller was replaced with ruggedized notebook personal computer (PC) and game-style hand held controller. Upgrade kits were procured to convert the entire fleet of MARCBots to MARCBot IV-Ns. In 2010, a radio upgrade kit was developed to convert the MARCBot IV-N wireless data link to the unlicensed frequency band for training in CONUS when the Army Spectrum Office disallowed the frequency employed OCONUS. Upgrade kits were procured for all robots used at CONUS sites. Both upgrades are being handled in-house at the RS JPO JRRF and JRRDs.

Future modernization being considered for this platform includes a software upgrade to a more capable version of the robot's operating system which will provide the following additional features:

- Line of sight radio range improvement of 50% through better network drivers
- Extension of the Non-line of sight range around physical barriers (daisy chain the robots) with radio repeaters enabled by the ad hoc mobile mesh network software (MANET) in the upgrade
- Collaboration between operators with all equipment on the mesh network visible and controllable by all operators
 - Shared video and pictures
 - Live chat via text messaging
 - Data file transfer between OCU nodes and bridging to external nodes
 - GPS location information of robots (military grid reference system [MGRS] coordinates and Falcon View and Google Earth maps)
- Plug-and-play modularity for devices with an IP interface (cameras, sensors, and audio) for future expandability and obsolescence mitigation

TALON Modernization

Modernization for the TALON robotic system has been ongoing over the last several years. As the workhorse for the Route Clearance (RC) teams, users of the TALON are consistently requesting greater capabilities and increased operational readiness time. The operation of the TALON during Route Clearance missions has increasingly become more of a mounted mission, as users

have become dependent on the safety of armored vehicles. Deployment of the TALON system onto the ground can now be accomplished without a soldier dismounting from the safety of their RG 31Mk5E vehicle. The Robotic Deployment System (RDS) outfitted on the RG 31 MK5E vehicle remotely stows and deploys the TALON to allow the completion of a RC mission. Moreover, the RS JPO has worked with the TALON OEM to develop a remote power on/off capability (CATNAP) for the RDS in order to conserve power during RC travel time when the TALON is stowed. The RDS and CATNAP capabilities are currently being fielded to RCP RG31MK5E trucks through PM Assured Mobility Systems.

Similar to the PackBot modernization effort, the configuration of RS JPO TALON robots is being baselined to a common platform configuration. Currently the RS JPO manages two different TALON configurations; TALON 3B and TALON 4. The TALON modernization plan calls for all TALON 3Bs to be converted to the TALON 4 configuration. The TALON 4 has greater capability and better modularity.

The TALON system has experienced modernization efforts, similar to those mentioned above, in the following areas:

- Radio technology
- BB 2590 battery tray in lieu of the OEM Lead Acid batteries
- Increased situational awareness through the WARVVS 180° wide angle robot camera

Future modernization efforts for the TALON may cover the following technology areas:

- Improved manipulator arm capability to allow for rotation of the arm at the base chassis
- Improved NLOS radio capability
- Wireless rechargeable station

Mini EOD Modernization

The Mini EOD has been a key component for the OEF EOD mission due to its light weight and compact size that allow it to be stored and carried in a soldier's rucksack. The Mini EOD is largely being used for the dismounted EOD missions in OEF. Usage of the Mini EOD has shown that the monacle display can lose its effectiveness depending on the user, as well as the type of environment it is used in. Efforts are underway to increase the effectiveness of the monacle display to eliminate glare issues as well as increase the number of adjustment features for the eye piece to accommodate different user preferences. By switching out the current tactical eyewear used with different glasses, the direct light glare experienced by some users has been virtually eliminated. Additionally, the off-the-face reflection from the eyewear lens is eliminated by the use of a Tac Eye boot and black-out selective lens cover. The adapter solution described is a single modification kit that retains monacle compatibility with both pairs of protective eyewear. The monacle modification kit will be evaluated by a variety of users to ensure the solution will fully correct the issues experienced by users.

Due to the Mini-EOD being the newest system fielded with limited quantities and User feedback, there is a limited modernization plan at this time. Some of the items being considered for modernization are:

- Secondary video output – allow for second video monitor to be used
- Heads down display to increase unit situational awareness
- Arch Camera – ruggedization to reduce failures of being used as a lift point
- Manipulator Arm – improve quick disconnect feature
- Increased NLOS radio communication capability

Small Unmanned Ground Vehicle (SUGV) Modernization

The SUGV is a teleoperated, man-packable, robotic vehicle intended for Military Operations in Urban Terrain (MOUT) and subterranean areas. The SUGV POR was initiated in 2009 and has since undergone the acquisition development cycle of design, develop, test and requirement verification. The SUGV acquisition strategy divided the development of key capabilities into two incremental phases referred to as Increment 1 (INC1) and Increment 2 (INC2). The SUGV system is envisioned to be capable of filling multiple Army roles that require the extension of the perception and influence of the dismounted Soldier. The variety of tasks includes reconnaissance, surveillance, and the application of numerous modular payloads.

Each of the test iterations of the SUGV revealed a small number of capabilities needing refinement in order to satisfy the Combat Developer's requirements. INC1 of the SUGV program system underwent its first characterization testing in FY09. Over 50 improvements were made following FY09 and FY10 tests, including an improved head/latch design, redesigned and strengthened neck structure, ruggedized camera, repositioned microphone, and increased communications ranges to over 900m. In February 2010, the SUGV INC1 successfully conducted qualification testing at Aberdeen Proving Ground to demonstrate that improvements made (as a result of FY09 and early FY10 characterization testing) effectively resolved the identified issues. The INC1 SUGV employs the following capabilities:

- Day/night/thermal cameras
- Laser range finder
- Infrared illuminator
- GPS
- Two-way speaker and microphone
- Ruggedized handheld controller

Future Modernization

The SUGV INC2 has a significant amount of enhancements and features over the INC1 version. INC2 SUGV enhancements are identified below:

- Upgraded software (Aware 2.0)
- Higher capacity central processing unit
- Militarized head – increased ISR capability
- Target location
- National Security Agency (NSA) approved radio
- Tether/spooler payload
- CBRN payload
- Electronic – Tactical Engagement Simulation System (E-TESS) payload
- Manipulator arm

Anti-Personnel Mine Clearing System, Remote Control (M160) Modernization

The M160 will undergo a modernization plan through the integration of product improvements. Future enhancements to the M160 system will follow a structured System Engineering (SE) process to identify and implement the optimal mix of capability enhancements to be incorporated. This process will be conducted by the IPT with guidance and coordination with the Maneuver Support Center of Excellence (MSCoE). Some possible improvements include:

- Development of a remote hitch attachment (vehicle recovery capability)
- Improvement of the mine clearance rate through continued development of the flail tool (chains and hammers)
- Development of an improved electronics package to include the use of additional sensors
- Implementation of lane and explosive marking systems
- Implementation of a common controller with updated video and communication

Prioritization of these and other improvements will be evaluated based on costs, capability improvements, operational effectiveness, and sustainment impacts.

In summary, the operation and sustainment of RS JPO systems referenced above has resulted in a vast amount of knowledge collected with regard to the use of systems, failures experienced, and additional capabilities desired. This knowledge has created a unique opportunity for the RS JPO to leverage lessons learned from current sustainment efforts and apply them to emerging PORs. RS JPO will continue to improve and modernize the currently fielded UGV fleet. This strategy will ensure an increase in operational life for each platform, decreasing the operation and sustainment cost.

3.3.2 Emerging Requirements and Risk Reduction Efforts

One of the key components for the RS JPO's strategy of developing and fielding the most technologically advanced and capable systems involves tracking, observing, and conducting assessments on emerging technologies and concepts. Operational type assessments provide valuable insight into the potential utility of prototype systems and technologies from a Warfighter perspective. The insight provided also affords the opportunity to identify and manage risk areas in emerging PORs or other R&D activities. A successful assessment may also lead to the development of a validated and funded urgent needs statement. Previous operational assessments have led to the development and fielding of robotic tool kits, enhancements to manipulation, tele-operation, and advanced optics for small robots. Risk reduction assessments, such as the Safe Operations of Unmanned Systems for Reconnaissance in Complex Environments (SOURCE) ATO, SANDI and SMSS, have shown that their perspective technology is reasonably mature and identified areas where further refinement is needed to reach the full set of capabilities required by the User. Identified below are the projected PORs where the RS JPO is actively tracking and involved with the risk reduction assessments.

Autonomous Mobility Appliqué System (AMAS):

AMAS is envisioned as an add-on kit that will functionally enable existing manned vehicles to be converted to optionally manned, unmanned, or mixed manned and unmanned modes of operation. Virtually all tactical combat vehicles are candidates for AMAS kit development. AMAS is comprised of an "A Kit" and a "B Kit." The A Kit includes the hardware box with the processing and decision-making software and payload control functions and will be common across all AMAS platforms. The B Kit includes platform specific cables, hardware, actuators, sensors and additional software as necessary to interface between the A Kit, platform's mission payloads, and the platform's environment. The AMAS CDD is currently in draft form with approval expected in late FY11. AMAS will leverage the lessons learned from a plethora of previous robotic kit development assessments (i.e., Route Runner, Rabbit, Combat Autonomous Mobility System [CAMS] and Convoy Active Safety Technology [CAST]). As part of AMAS risk reduction efforts, the RS JPO is currently involved in the operational assessment of SANDI.

Supervised Autonomy to Neutralize and Detects IEDs (SANDI)

The SANDI program is an unmanned vehicle system designed to provide a standoff capability in route clearance and convoy missions by operating in front of manned vehicles. The remotely operated unmanned vehicle can act as a stand-alone Victim-Operated IED (VOIED) system or support a variety of neutralization payloads and detection sensors. SANDI is capable of operating at higher speeds than traditional tele-operated vehicles. The SANDI program is currently undergoing an assessment in OEF to help establish the limitations of current sensor fusion technologies when employed in a tactical environment. Additionally, through the deployment of the SANDI platform in an operational environment, we increase Warfighter familiarity and acceptance of large unmanned vehicles on the battlefield. This familiarization may reduce some of the common safety concerns associated with large unmanned vehicles. It is envisioned that the AMAS POR

will heavily leverage the ANS POR, SANDI, and other appliqué risk reduction programs the RS JPO has been associated with over the last 15 years.

Squad Multi-Purpose Equipment Transport (S-MET)

S-MET will provide the ground combat Soldier a surrogate, squad-sized unmanned platform, which will serve as a utility and cargo transport for dismounted small unit operations. The concept of the S-MET is to carry the approach march load of a squad and do so without negatively impacting the squad's operations. The S-MET will have the capability of operating in all types of terrain while in three control regimes; tele-operation, semi-autonomous and autonomous.

A current concept platform being used as a risk reduction is the SMSS is an unmanned platform primarily designed to serve as a utility and cargo transport for dismounted small unit operations. The vehicle is meant to lighten the load of the nine- to 13-man squads or teams by carrying their equipment, food, weapons, and ammunition (up to 1,200 pounds) on unimproved roads and cross-country terrain. The SMSS systems have participated in both a Military Utility Assessment (MUA) and an independent evaluation in mountainous terrain. Results of both the assessment and evaluation identified needed improvements and further development in technologies in order to meet the requirements in the S-MET CDD. The results of the MUA were used to inform the CDD and its development to ensure it is written with clear, reasonable and feasible requirements in relation to current and near future technologies. Both of the evaluations were also beneficial to the RS JPO, as it informed a decision for the program office to send two SMSS vehicles into OEF for a Forward Operating Assessment for further risk reduction and requirements validation.

Other efforts have been and currently are being used as risk reduction efforts in relation to the S-MET requirement. The Multifunctional Utility Logistics Equipment (MULE), Autonomous Expeditionary Support Platform (AESP), Squad Robotic Support Utility Vehicle (SRSUV) are current concept platforms that are being leveraged for risk reduction purposes through various testing and demonstrations.

Multi-Mission Unmanned Ground Vehicle (MM UGV)

The MM-UGV will provide the maneuver platoon with an armed unmanned capability, and the maneuver company with the capability to detect, mark, and report IEDs. The MM-UGV consists of two variants explained below:

- The lethal variant has the capability to locate and destroy enemy platforms and positions in any operational environment. It can provide Reconnaissance, Surveillance and Target Acquisition functionality from an over watch position, providing the ability for direct fire support that will allow Soldiers to remain in a covered/concealed position. It can be maneuvered semi-autonomously or by tele-operation, based on the operational tempo using the ANS. The MM-UGV articulating suspension allows it to traverse complex terrain
- The C-IED variant will provide the maneuver company with the capability to detect, mark, and report IEDs. The C-IED variant will deploy an array of sensors to enhance IED detection and a manipulator arm to probe suspected locations. The C-IED platform will mark and report the IED, allowing follow-on units to bypass the IED. The C-IED can be operated by tele-operation or semi-autonomously to maximize safe stand-off distance for the Soldier

The CMP chassis is serving as a risk reduction effort to the development of the MM UGV variants. The CMP chassis provides superior mobility, built around advanced propulsion and articulated suspension system. The testing and refinement of the CMP chassis will enhance the MM UGV's ability to negotiate complex terrain, obstacles, and gaps that mounted and dismounted troops will encounter. Examples of specific risk reduction activities being conducted on the CMP

include engine lifetime testing, mobility and non-pneumatic tire testing. Results from testing done on the CMP will be leveraged to ensure success in meeting MM UGV high risk requirements.

3.3.3 Interoperability

Interoperability is integral to the success of missions using unmanned systems, and represents a long term objective of the RS JPO and its stakeholders. The urgent needs in theater and corresponding rapid acquisition approach during recent years have resulted in a current fleet of robotic systems that generally do not interoperate with each other or with external systems. Additionally, current systems are not optimized to share information into other domains beyond UGS. As payloads, sensors, software, and computing devices are anticipated to evolve much faster than the base platforms, creating interoperable interfaces for enhanced modularity represents an opportunity to minimize future life cycle costs and adapt rapidly to changing threats or new available technologies. The Combat Developer community is also calling for interoperability as a critical element to the future UGS fleet. Based on these concerns and opportunities, the RS JPO has initiated a strategic effort to develop the necessary elements for achieving interoperability.

The RS JPO Interoperability IPT has been formed with representation from a variety of agencies who possess the critical expertise required to define an integrated and optimized path toward interoperability. The IPT's objective is to define interoperability standards for integration across UGS, while leveraging the interoperability efforts of the UAS community and the NAVEODTECHDIV to the greatest extent possible. The scope for this effort includes defining the following:

- Open architecture and interfaces
- Common control standards
- Communications data link standards
- Modular payload interfaces
- Conformance, verification, and validation criteria

The Interoperability IPT will establish, adopt and apply interoperability standards for UGS by working closely with the Combat Developers, the S&T community, and private industry. The SAE Standard AS-4 (JAUS) will form a basis for the interoperability architecture.

Interoperability Methodology

The RS JPO intends to achieve these objectives through the development and use of IOPs. These IOPs will contain a set of interface definitions and requirements for physical, electrical, software, control, data, communications, and human elements, as well as implementation guidance for SAE AS-4/JAUS message sets.

The following overall process is being utilized for the development and application of the IOPs:

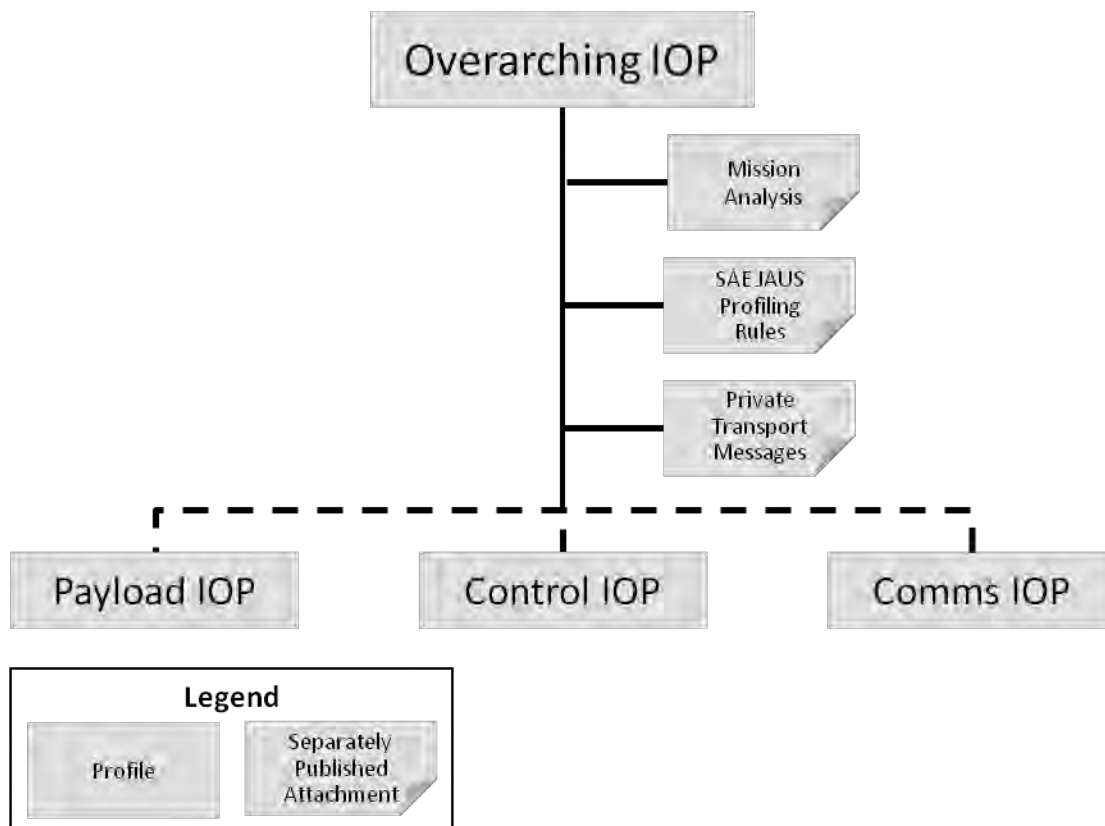
- Develop and refine Mission Profiles and Use Cases – a summary of operational requirements and how UGS are currently being used
- Decompose to understand Functional Requirements – a listing of what functions the UGS fleet must perform, in relation to interoperability
- Develop IOPs to define software and hardware interfaces – this will lead to the publishing of the IOPs themselves
- Refine IOPs over time to outpace TRADOC requirements and technology advancements – an annual publishing of IOPs is planned, starting with IOP V0 by the end of FY11
- Utilize RSIL to Validate IOPs and Assess Conformance to them – this will be used in confirming that the IOPs ensure interoperability as planned, and in determining commercial vendors' level of compliance with the IOPs

- Implement IOPs in Performance Specifications for UGV Acquisitions – this will ensure that the actual fielded system acquisitions are interoperable

The IOPs consist of a series of documents, depicted in Figure 16 – RS JPO Interoperability Profiles (IOPs) Hierarchical Structure:

- Overarching IOP – Defines platform level mobility, network, messaging and environmental requirements, and their conformance/validation criteria
- Mission Analysis Attachment – Includes a summary of operational requirements and use cases
- SAE JAUS Profiling Rules Attachment – Includes specification, clarification, and implementation guidance on the SAE JAUS standards
- Private Transports Attachment – Includes guidance on the formulation of messages not currently within the SAE JAUS message sets
- Payload IOP – Defines payload classifications, standards, requirements, and conformance approach
- Communications IOP – Defines communication standards, requirements, and conformance approach
- Control IOP – Defines Operator Control Unit logical architecture, standards, requirements, conformance approach, and command and control messages

Figure 16. RS JPO Interoperability Profiles (IOPs) Hierarchical Structure



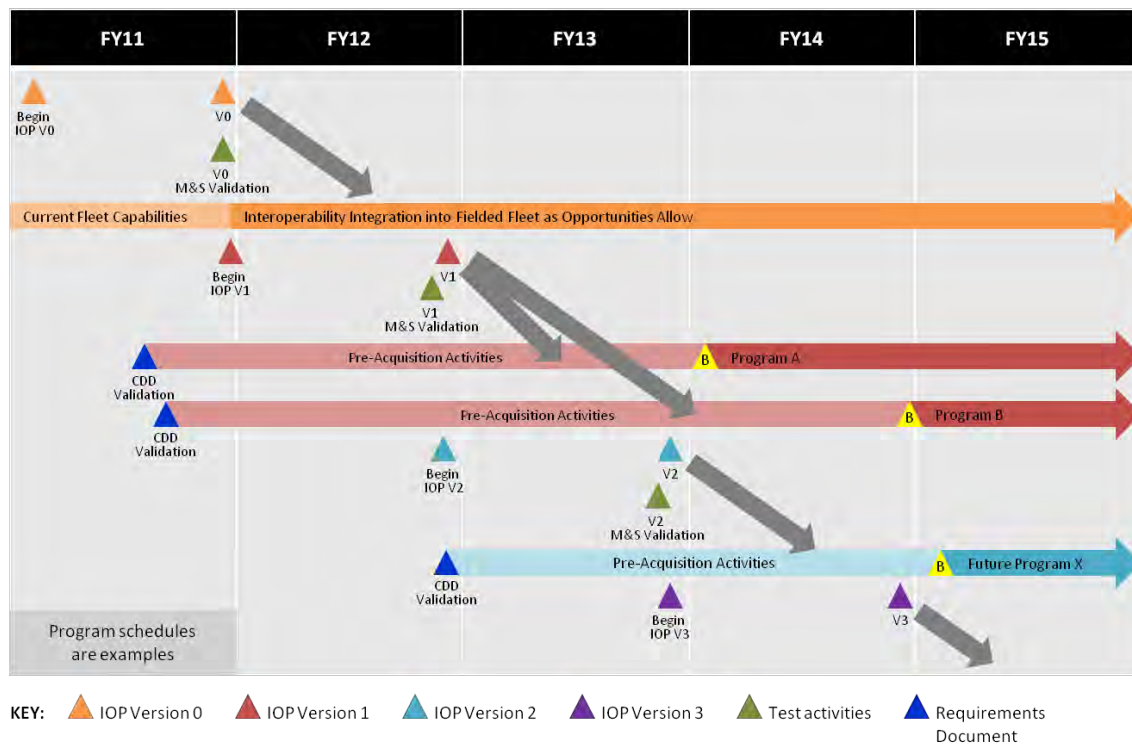
In November of 2010, a government/industry WIPT structure was stood up in order to strengthen the long term collaboration and synchronization of ideas, and to formally develop the IOP V0 package. The WIPT structure includes representatives from a variety of government organizations, as well as industry volunteers from over 35 companies. These individuals are divided into

Overarching, JAUS Profiling, Payload, Control, and Communications WIPTs, with the mission of publishing the IOPs and updating them over time.

Schedule

As indicated in Figure 17 – RS JPO IOP Adoption Process in Defense Acquisition Framework, IOP V0 will be published by the end of FY11. The scope of IOP V0 is limited to capabilities that are currently common to fielded systems. Fielded platforms will be modified to comply with IOP V0 if opportunities present themselves for modification of existing systems, in terms of requirements and funding. During FY12, IOP V1 will be published, which will include an expanded set of capabilities, consistent with those capabilities in the nearest term emerging PORs. Those PoRs will then be required to comply with IOP V1. The process will continue each subsequent FY, with IOP V2 being published in FY13 affecting future PoRs at that time, and so forth.

Figure 17. RS JPO Interoperability Profile (IOP)
Adoption Process in Defense Acquisition Framework



Implications to Stakeholders

The decision for the RS JPO to pursue this interoperability approach will have a number of implications to UGS stakeholders. For the RS JPO, realization of these interoperability objectives will mean a lowered life cycle cost for systems over time, as it will broaden the base of competition and change the industrial landscape. Additionally, it will give the RS JPO the ability to rapidly adapt its systems in reaction to changing user requirements and technological advances over time. This means enhanced capability for the Warfighter and reduced cost to the taxpayer.

For the Combat Developer community, the results of this interoperability effort will mean realization of the capabilities envisioned in the Unmanned Systems ICD and related requirements documents.

For industry, this interoperability approach means that companies with business models that favor closed-architecture products will ultimately either lose market share or need to adapt their busi-

ness strategies. For companies who have business models based on open architecture and non-proprietary interfaces, or for those who want to market their payloads to a larger variety of OEMs, this means an opportunity for increased business.

As the RS JPO/Army continues to transition systems and capabilities into the hands of the Warfighter, interoperability matures and will result in a standard scalable capability allowing manned and unmanned platforms to operate between tele-operation and semi-autonomous modes.

3.4 Conclusion

In Summary, as the RS JPO/Army continues to transition systems and capabilities into the hands of the Warfighter, interoperability matures and will result in a standard scalable capability allowing manned and unmanned platforms to operate between tele-operation and semi-autonomous modes. Acquisition and life cycle costs are expected to decrease due to fewer platform types and increasing quantities. Some specialized UGV systems will still be required for emerging requirements but should share common sub components when possible. The long-term capability gaps as well as the RS JPO UGV strategy, are evolving to address the need for systems to be transportable (vehicle, self, soldier) and improving robotic appliqué kits.

Appendix A: RS JPO Systems/Programs Portfolio

A1 Anti-Personnel Mine Clearing System, Remote Control (M160)



Mission: Area Clearance and Route Clearance missions

User Service: U.S. Army

Manufacturer: DOK-ING D.O.O., Demining and Manufacturing, Zagreb, Croatia

Program Description:

The Anti-Personnel Mine Clearing System, Remote Control (M160) is a component system in the Area Clearance FoS that responds to the U.S. Army Area Clearance Family of Systems CPD, approved by HQDA Revision 1, 11 March 2010. The Area Clearance FoS provides the capability for current and future Joint and Army Forces to clear the full range of anti-personnel (AP) mines quickly and safely to support operational deployments. The FoS will be employed at Division and Corps levels and generally task-organized with the Engineer Brigade or Combat Support Brigade. The M160 is a legacy, contingency system which transitioned to a post-Milestone B, ACAT III Non-developmental Item program.

The M160 is an improved version of the COTS DOK-ING MV-4A. Integration of performance improvements to the MV-4A mechanical, electronics and control and communications subsystems increased reliability and durability resulting in the production of the DOK-ING MV-4B model.

An authorized nomenclature and model record number for the Anti-Personnel Mine Clearing System; Remote Control MV-4B was released by the Standardization Branch on 04 March 2010. The new model number, M160 has replaced the OEM model number (MV-4B).

The M160 tracked combat engineer vehicle is designed for teleoperation by Soldiers from either mounted or dismounted positions to neutralize AP mines by destroying or detonating them with its rotating flail head. It has been proven to be reliable and very effective in clearing AP mines and explosives in OND and OEF. The vehicle will continue to be improved through the modernization plan to provide stand-off protection to soldiers as areas are cleared of AP mines.

System Characteristics:

Size 209" L x 80.1" W x 58.3" H (Flail arms extended)
Weight (robot) 12,184 lbs
Weight (OCU) 10 lbs
Endurance 2-7 hrs (depending on fuel consumption rate)
Max Speed 3.1 mph (5kph)
Engine 275 hp Perkins Turbo Diesel engine

Payloads: N/A

Capabilities:

- Clearing capacity is 500-2000 square meters per hour depending on terrain
- Capable of clearing a path 68 inches wide and up to 8 inches in depth
- Four cameras (one on each side, front camera has an IRIS Control and Zoom capability)
- OCU has video capability

Program Events and Associated Timelines:

- Log Demo: Completed in September 2010
- Initial Operational Test and Evaluation (IOT&E) Event: 28 November 2010 – 10 December 2010
- Program of Record Safety Confirmation received – 23 February 2011
- MDA Program Certification (MS C): 3rd Qtr FY11
- Full Materiel Release/Type Classification Standard: 1st Qtr FY12
- First Unit Equipped: 2nd Qtr FY12
- Initial Operational Capability (IOC): 3rd Qtr FY12
- Full Operational Capability: 1st Qtr FY13
- Fielding: 48 Systems are currently fielded with an additional 17 systems fielded by FY14 which will meet the Army Acquisition Objective total of 65

Sustainment Plan:

The M160 will be fielded to Active Duty, National Guard, and Reserve units from 2011 to 2014. Supportability for the M160 System is outlined in the Supportability Strategy, dated June 2010. M160 Supply and maintenance support will be provided by the JRRF, at JRRDs and the OEM, until transitioned to the Standard Army Supply System and Organic Maintenance in late FY14.

The RS JPO is currently conducting a Type I Business Case Analysis (BCA) to determine if the M160 system is a potential candidate for Performance Based Logistics (PBL). The BCA will support RS JPO management in determining the best use of organic/commercial partnering resources for sustaining the M160 system.

A2 PackBot Family of Systems



Mission: Provide the Warfighter standoff for missions involving explosive or hazardous materials, reconnaissance, and other Combat Engineer missions

User Service: U.S. Army and U.S. Marine Corps

Manufacturer: iRobot Corporation, Bedford, MA

Program Description:

The PackBot is a small, teleoperated, tracked robotic platform. The family of vehicles was designed to inspect and clear suspicious objects during IED and EOD missions. The robot provides a safe standoff distance for the Soldier performing an explosive residue detection, interrogation and removal of suspicious objects. The system includes a remote controlled articulated arm with a gripper and a pan/tilt/zoom color surveillance camera with ultra low-light capabilities. The robot operates at speeds up to 5.8 miles per hour, enabling fast, tactical maneuvers.

The first fielded PackBot robots were the PackBot 500 and the PackBot FIDO, both with a 3-link arm with gripper for manipulating and carrying objects and a proprietary suitcase controller (Portable Command Console (PCC) for the OCU. The arm extends 80", and can lift 10 pounds at full extension and 30 pounds close to the chassis. The head, shoulder and gripper independently rotate a continuous 360 degrees with an auto-focus, 312X zoom color camera that enables the robot to identify, lift, carry, and manipulate small objects. The fully integrated FIDO sensor is used for explosive detection.

A smaller, lighter version of the PackBot was later fielded for route reconnaissance missions. The PackBot FasTac has two smaller arms (SAM, CAM), flippers without tracks, and a smaller, lighter weight, ruggedized PC for the OCU. The FasTac uses a modern version of the original PackBot 500 chassis (the PackBot 510) with a higher frequency embedded radio. The CAM has three degrees of freedom with the same highly capable color zoom camera seen on the 3-link arm, and can extend 29" to view heights up to 41". The SAM has four degrees of freedom with continuous wrist rotation and 185 degrees shoulder pitch. It extends 42" and can lift five pounds at full extension. A software upgrade on the PackBot 510 platform to Aware 2 enables plug-and-play interoperability of all 500 and 510 series payload on the FasTac chassis.

System Characteristics:

	<u>PackBot 500 (3-link arm, PCC)</u>	<u>PackBot 510 (CAM & SAM OCU)</u>
Size	27" L x 20" W x 16" H.....	27" L x 20" W x 12" H
Weight (robot)	68 lbs	53 lbs
Weight (OCU)	41 lbs	13 lbs
Lift Capacity	10 lbs full extension; 30 lbs close	5 lbs full extension; 15 lbs close
Endurance	3 to 4 hrs.....	3 to 4 hrs
Max Speed	Up to 5.8 mph	Up to 5.8 mph

Payloads (options):

- Fiber optic spooler
- FIDO explosive detector
- Water bottle charge disrupters
- Enhanced awareness package (compatible with FasTac arms only)
- Thermal camera
- Comm select radio (PackBot 500 series only)
- BB2590 battery cradle upgrade (PackBot 500 series only)

Capabilities:

- Carry/place explosive charges
- Detect explosives such as RDX, TNT, PETN
- 312x zoom (26X optical, 12X digital)
- Both white and NIR LED arrays for illuminating in all ambient light conditions
- Camera mounted on a slip ring, and can rotate continuously 360 degree
- Modular chassis capable of accommodating a number of different payloads
- Ability to traverse rough outdoor terrains as well as operate in urban environments
- Trackless flippers can be upgraded to tracked flippers

Program Events and Associated Timelines:

RS JPO maintains a fleet of PackBot systems in support of OEF and OND operational and CONUS/OCNUS training requirements identified through an ONS or JUONS.

For the PackBot FIDO, no new requirements exist, and the PackBot 500 chassis is no longer available from the manufacturer. Current PackBot FIDO and EOD robots will be upgraded to the PackBot 510 chassis with Aware 2 software for ongoing sustainment. Future requirements can be met by utilizing the 510 chassis with plug-and-play modularity of the Aware 2 software. Payloads from existing PackBots are modular with the upgraded chassis, and can be used along with any new payloads developed to meet mission needs.

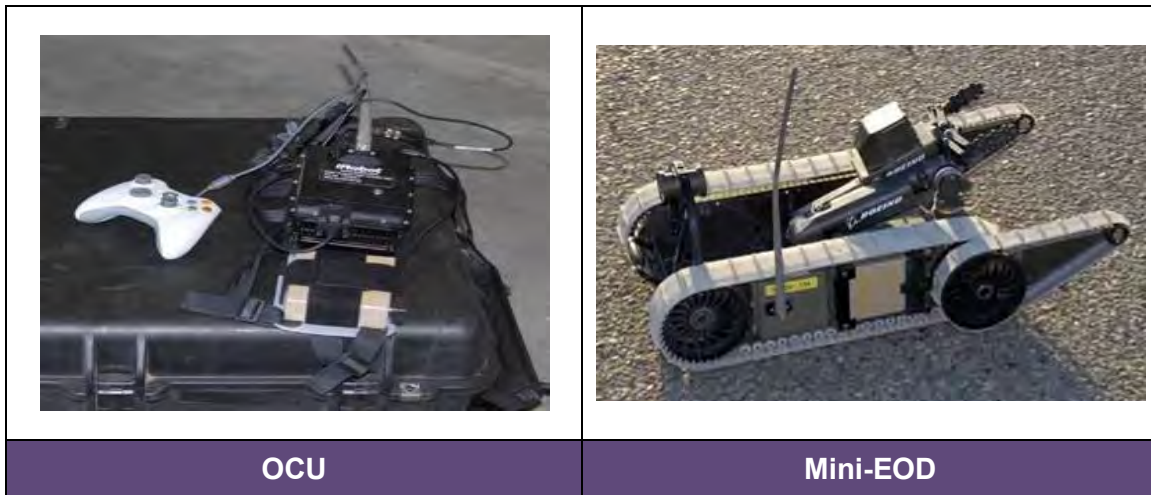
A Safety Confirmation was received in March 2008 for the FasTac system. All FasTac robots will be upgraded to the Aware 2 software in 2011.

Sustainment Plan:

The PackBot was designated by the Capabilities Development for Rapid Transition process as sustain for wartime and will continue to be sustained until overseas contingency operations cease.

The current sustainment for the PackBot FoS is provided by CONUS and OCONUS JRRDs. The JRRDs either replace the entire inoperable robot or replace the broken component and ship it back to the manufacturer for repair.

A3 Mini-EOD



Mission: Identify and neutralize IEDs

User Service: U.S. Army, U.S. Marine Corps, U.S. Navy, U.S. Air Force

Manufacturer: The Boeing Company (Prime) with iRobot Corporation (Sub)

Program Description:

The Mini-EOD system supports a JUONS to assist in EOD operations requiring a smaller robot. The Mini-EOD identifies and neutralizes roadside bombs, car bombs, and other IEDs and is specially designed for locating, identifying and disarming explosive and incendiary devices, and collecting forensic evidence.

The Mini-EOD is a small, lightweight, Modular Lightweight Load-carrying Equipment (MOLLE) pack transportable vehicle operated from a wearable OCU. The Mini-EOD uses a chassis with four cameras allowing a forward/rear facing Wide-Field of View (WFOV), gripper, and body chassis view while utilizing BB-2557 batteries. The Mini-EOD uses a manipulator arm. Together, the vehicle and OCU weigh less than 35 lbs, and can be stowed in a military rucksack or MOLLE pack.

System Characteristics:

Size	24" L x 18" W x 11" H
Weight (robot)	30 lbs
Weight (OCU)	4.4 lbs
Endurance	90 min
Max Speed	5.8 mph

Payloads:

- Manipulator arm
- Arch camera
- Front and rear cameras
- Lights

Capabilities:

- 360 degree pivotal arm that can lift ten pounds with a reach of two feet beyond the body of the robot
- Capable of moving over most types of terrain
- Night and low-light capable
- Identify and neutralize roadside bombs, car bombs and other IEDs
- Capable of collecting forensic evidence
- Rucksack/MOLLE pack portable
- Wearable OCU
- Capable of 5.8 mph with 5-lb payload

Program Events and Associated Timelines:

More than 320 Mini-EOD systems are being sustained CONUS/OCONUS.

Sustainment Plan:

Mini-EOD systems are currently being fielded in support of contingency operations and are supported only through OCO funding. As a result, no long term sustainment strategy has been developed.

Current sustainment for the Mini-EOD is provided by CONUS and OCONUS JRRDs. The JRRDs either replace the entire inoperable robot or replace the broken component and ship it back to the manufacturer for repair.

A4 TALON Family of Systems



Mission: Engineer Support/Reconnaissance and Surveillance missions

User Service: U.S. Army

Manufacturer: QinetiQ North America, Waltham, MA

Program Description:

The TALON IIIB and IV platforms provide commanders the ability to detect, identify, and neutralize suspected explosive hazards using a tele-operated system. The platforms utilize an articulated arm and gripper, multiple illuminated cameras, a pan/tilt surveillance camera, long range radios, and a ruggedized OCU to execute missions. Additional capabilities available for the TALON IV Engineer include three infrared (IR) cameras, a 300:1 color zoom with wide-angle camera, and a JAUS-compliant design that allows for modular plug-and-play upgrades.

System Characteristics:

	<u>TALON IIIB</u>	<u>TALON IV</u>
Size	34" L x 22.5" W x 11" H.....	34" L x 22.5" W x 11" H
Weight (robot)	160 lbs	168 lbs
Weight (OCU)	45 lbs	44 lbs
Lift Capacity	10 lbs full extension; 30 lbs close	5 lbs full extension; 15 lbs close
Endurance	3 hrs	4.5 hrs
Max Speed	5.2 mph	5.2 mph

Payloads (Standard [S] and Optional [O]):

- 2-stage manipulator arm w/ wrist gripper (S)
- Extendable pan/tilt/zoom video camera (S)
- Analog video (S)
- COFDM video (O)
- FIDO sensor (O)
- CATNAP remote power on/off system (O)
- Battery tray for BB2590 Li-Ion batteries (O)
- Quick disconnect universal mounting bracket (O) [TALON IV only]
- Hazardous material sensor suite (O) [TALON IV only]
- 2-channel explosive firing circuit (O) [TALON IV only]
- WARVVS camera (O) [TALON IV only]

Capabilities:

- Explosive ordnance disposal using the attached gripper
- Extended detection ranges using the heat contrast detection cameras, night navigation system, and visual cameras
- Fiber optic tether in the event of unusable RF links

Program Events and Associated Timelines:

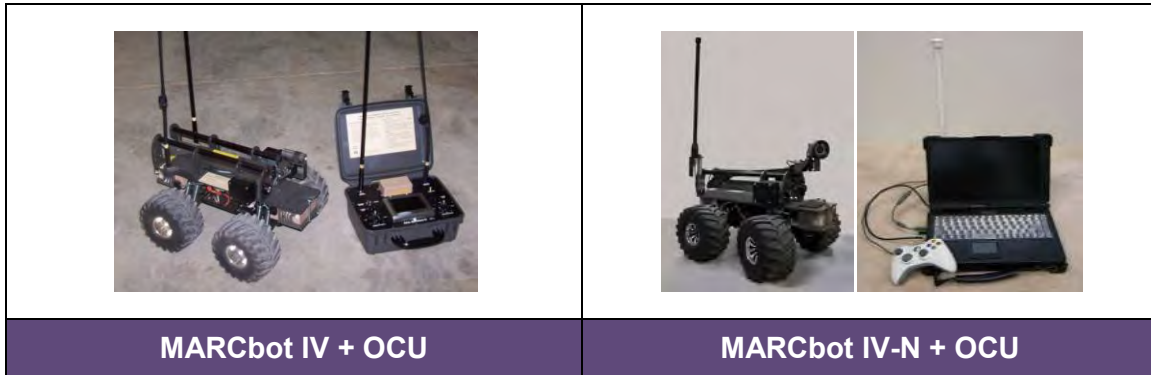
RS JPO maintains a fleet of TALON IIIB and IV systems in support of OEF and OND operational and CONUS/OCONUS training requirements identified through an Operational Needs Statement or Joint Urgent Operational Needs Statement.

Sustainment Plan:

TALON systems are currently being fielded in support of contingency operations and supported only through OCO funding. As a result no long term sustainment strategy has been developed. There is a desire in RS JPO to move towards a uniform fleet to reduce sustainment footprint and configuration management issues.

In order to sustain the current fleet of TALON systems in theater today, the current sustainment is provided by CONUS and OCONUS JRRDs. The JRRDs either replace the entire inoperable robot or replace the broken component. A plan is in place in order to provide RS JPO the ability to ship broken components back to the manufacturer to have them repaired.

A5 MARCbot



Mission: MARCbot serves as a wheeled reconnaissance robot designed to provide the Warfighter with a remote, look only capability.

User Service: U.S. Army and U.S. Marine Corps

Manufacturer: Applied Geo Technologies, Inc., Choctaw, MS

Program Description:

The MARCbot IV-N is a low-cost IED investigation capability used by U.S. Army and U.S. Marine Corps personnel to provide standoff investigation of suspected IED emplacements. MARCbot IV-N uses an articulating arm to maneuver a camera into position to confirm or deny a suspected IED. The robot is not equipped with a manipulator arm or gripper for manipulating or lifting objects. The ability to confirm IEDs reduces the number of IED false alarm calls and allows the patrol or convoy to proceed with minimal exposure to hostile environments. The MARCbot IV-N is an upgrade to the previously fielded MARCbot IV. All fielded MARCbots will be upgraded to the MARCbot IV-N configuration. Modifications include a digital radio at a higher frequency and improved OCU that consists of a ruggedized PC with game-style hand held controller. The U.S. Government has purchased a Technical Data Package (TDP) with Government purpose rights for the MARCbot IV-N.

System Characteristics:

Size 24" L x 19" W x 13.5" H
 Weight (Robot)..... 35 lbs
 Weight (OCU) 9.5 lbs
 Endurance 4 hrs
 Max. speed..... 5 mph

Payloads:

- Retractable pan and tilt color camera with near-infra red LED lighting for low light imaging

Capabilities:

- Remote observation distance greater than 100 meters
- Low-light camera and LED arrays for nighttime mission capability
- Pan/tilt camera can be raised to 3 feet and extended to 1.2 feet to inspect container and other obstacles

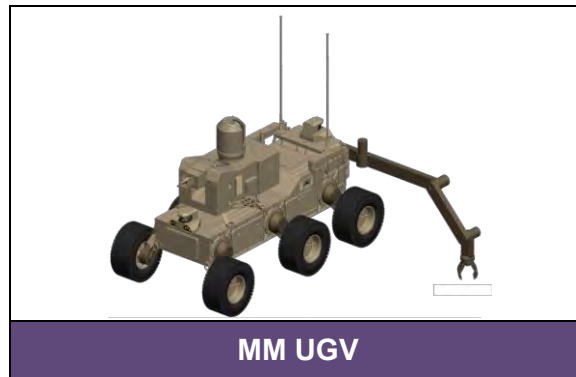
Program Events and Associated Timelines:

MARCBot IV-N received a Safety Confirmation (SC) on 26 August 2008. The contractor delivered an additional 496 MARCBot IV-Ns to supplement the already existing 850 MARCBot IVs. These additional units will be used to support OND, OEF, Foreign Military Sales, and training and spares. All current MARCBot IVs will be upgraded to the MARCBot IV-N configuration with the installation of the Line Replaceable Unit (LRU) radio/OCU upgrade kit.

Sustainment Plan:

Systems fielded under JOUNS. The MARCBot is currently designated as a wartime sustained system and will continue to be sustained until OCO ceases.

A6 Common Mobility Platform (CMP)



MM UGV

Mission: Route Reconnaissance and Counter IED Detection

User Service: U.S. Army

Manufacturer: TBD, via full and open competition of the EMD contract

Program Description:

The CMP is a 2.5-ton armored UGV base platform that provides space, weight, power, cooling, and network interfaces for current and future medium self transportable UGV mission equipment payloads. The CMP provides semi-autonomous and tele-operation based maneuver and supports complex mobility requirements across the range of military operations (ROMO). The CMP can accommodate payloads of up to 2300 lbs.

Systems Characteristics:

Size 177.3" L x 90" W x 89.4" H (141" H to top of highest antenna)
 Weight (CMP) 7,325 (includes 2,000 lbs payload)
 Weight (OCU) TBD
 Endurance 250 km
 Max Speed 65 kph
 Engine 135 HP Multi-Fuel Diesel Engine

Payloads:

Lethal Variant

- M240 machine gun
- JAVELIN missiles
- M66mm Smoke Grenade Launcher
- Electro-optical/infrared sensor
- ANS

C-IED Variant

- Multi-spectral threat sensors
- Air detection system
- High definition cameras
- Robotic manipulator arm
- ANS
- Marking system
- IED reporting system

Capabilities:

- Semi-autonomous operations: step of 1m and gap of 1.8m
- Dash speed: 0-48 kph in 12 seconds
- Open and rolling terrain: 35+ kph (on off-road course)
- Hard surface speed: 65 kph (on concrete surface)
- Move on route (MOR): blind MOR, MOR with perception
- Non-line of sight vehicle control
- Sling Load 2 per CH-47
- C-130/C-17 Air-Droppable

Program Events and Associated Timelines:

- CMP CDR 1st Qtr FY11
- CMP FDR – 3rd Qtr FY11
- CMP Software CDR – 1st Qtr FY12
- CMP Test Readiness Review (TRR) – 4th Qtr FY12
- First CPM delivery (2) – 1st Qtr FY13

Sustainment Plan:

Maintenance planning will be performed in accordance with the Army's two-level maintenance (2LM) concept. The operators and combat repair teams will be responsible for field-level maintenance. Field maintenance consists of operator (crew) maintenance on the actual end item in the tactical area (80%), and maintenance done by the combat repair team (20%).

The MM-UGV maintenance concept is within the U.S. Army guidelines of a 2LM concept. The current philosophy is that field-level maintainers will remove and replace failed MM-UGV LRU and Line Replaceable Modules (LRMs) in accordance with operator and maintainer tasks contained within the MM-UGV Interactive Electronic Technical Manual (IETM). The replaced LRMs, IPM, LIPM, MMWR, and GPS/INS are to be returned to the contractor for repair.

A7 XM1216 Small Unmanned Ground Vehicle (SUGV)



Mission: Situational Awareness and ISR for the dismounted Soldier

User Service: U.S. Army

Manufacturer: iRobot Corporation, Bedford, MA

Program Description:

The SUGV is a light weight, Soldier-portable, UGV capable of conducting military operations in urban terrain, tunnels, sewers and caves. The SUGV provides SA/SU and ISR to dismounted Soldiers enabling the performance of manpower intensive or high-risk functions without exposing Soldiers directly to the hazard. The SUGV modular design allows multiple payloads to be integrated in a plug-and-play fashion. The SUGV is capable of carrying up to four pounds of payload weight.

Systems Characteristics:

Size	30" L x 17.2" W x 6.5" H (stowed), 26" H (extended)
Weight (robot)	35 lbs
Weight (OCU)	15 lbs
Endurance	6 hrs
Max Speed	6.2 mph
Engine	N/A

Payloads:

- COTS Sensor Head
 - Day/night/thermal cameras (Increment 1)
- Laser range finder (Increment 1)
- IR illuminator (Increment 1)
- GPS (Increment 1)
- Two way speaker and microphone (Increment 1)
- Ruggedized handheld controller (Increment 1)
- Militarized sensor head (Increment 2) (replaces COTS sensor head)
 - Improved day/night/thermal cameras
 - Inertial measurement unit
- NSA approved radio (Increment 2)
- Tether/spooler (Increment 2)
- CBRN (Increment 2)
- E-TESS (Increment 2)
- Manipulator arm (Increment 2)

Capabilities:

The SUGV provides SA/SU and ISR

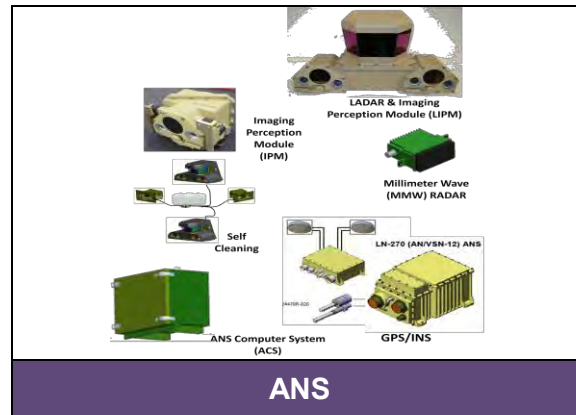
Program Events and Associated Timelines:

- 1st Brigade fielding, 3rd QTR FY11
- 2nd Brigade fielding, TBD
- 3rd Brigade fielding, TBD
- INC2 Critical Design Review (CDR), 4th QTR FY11

Sustainment Plan:

Contractor Logistics Support for the first three years

A8 XM155 Autonomous Navigation System (ANS)



Mission: Force Application, Logistics, Force Support

User Service: U.S. Army

Manufacturer: General Dynamics Robotic Systems (GDRS), Westminister, MD

Program Description:

ANS, designated as XM-155, is the mission sensor and computational package that will be integrated on the CMP to provide robotic semiautonomous capability. The ANS will meet the requirements defined in the draft MMUGV CDD for mobility and safety of an UGV platform. The ANS primary system components are: Laser Detection and Ranging (LADAR) Imaging Perception Module (LIPM), Imaging Perception Module (IPM), Millimeter Wave Radar (MMWR), GPS/INS, self-cleaning system, precision timing module, and the ACS. ANS provides GPS/INS for core navigation, targeting support and timing. ANS provides the sensors and software processing for unmanned operations for day, night, all weather conditions and the platform mobility control for on/off roads, cross country, complex terrain, and dynamic, unstructured environments such as urban road networks. MMWR provides tracking in rain, smoke, or fog along with an early warning for approaching vehicles with high closing rates while the LIPM and IPMs provide obstacle avoidance, human detection, and situational awareness. ACS provides System of Systems Common Operating Environment (SoSCOE) interface, path planning, video processing, hardware sensor processing, object processing, and platform speed and curvature commands. The ANS software development baseline is a three-phase approach. Phase 1 supported simulation and early prototypes using external waypoints at limited speeds. Phase 2 will support early testing and demonstration of ANS capability with prototype operational hardware on current force platforms to reduce risk and improve performance. Phase 3 will meet all requirements for platform speed, terrain types, and operational modes: move-on-route, leader-follower, aided tele-operation, and tele-operation. ANS will provide the hardware and software for unmanned navigation required for UGV platforms to be fielded under this program element and future manned and unmanned ground vehicles. In July 2009, the ANS effort associated with Manned Ground Vehicle (MGV) integration was terminated; however, the ANS program is prepared to work requirements generated by the Ground Combat Vehicle program.

Systems Characteristics:

Size	Varies with configuration
Weight (robot)	Varies with configuration
Endurance	Same as host vehicle
Max Speed	Same as host vehicle (up to 65 kph)
Engine	Same as host vehicle

Payloads: N/A

Capabilities:

- Enables host vehicle to conduct missions autonomously
- GPS/INS core navigation, targeting support, and timing
- Alternative routes
- Day/night capability and all weather
- Vehicle position data
- Conduct semi-autonomous navigation, remote operations
- Detect positive and negative obstacles
- Mobility control for on/off roads, cross country and complex terrain
- Support for situational awareness

Program Events and Associated Timelines:

- ANS CDR – completed March 2010
- Hardware and Phase I software delivery – scheduled for April 2012
- Phase II software delivery – scheduled for October 2012
- Production Readiness Review – scheduled for December 2012

Sustainment Plan:

Maintenance planning will be performed in accordance with the Army's 2LM concept. The operators and combat repair teams will be responsible for field-level maintenance. Field-level maintenance consists of operator (crew) maintenance on the actual end-item in the tactical area (80%), and maintenance done by the combat repair team (20%).

ANS will be provisioned as a Class IX secondary item to its host platform. ANS PBL will be addressed as part of the host platform PBL requirements. PBL is the preferred approach for executing affordable product support so that the accountability and responsibility for the integration of support elements is linked to specific Warfighter performance requirements for weapon system readiness and operational capability. Support for ANS prototype systems will be provided by RS JPO, the Principle System Integrator (PSI), and contractors. It is envisioned that the OEM will provide sustainment support in conjunction with the Principle System Provider (PSP).

Appendix B: Acronym List

..... #	
4D/RCS	4 Dimension/Real-time Control System
..... A	
ACAT	Acquisition Category
ACS	Alternate Control System, ANS Computer System
AEODRS	Advanced EOD Robotic System
AMAS	Autonomous Mobility Appliqué System
AMDS	Advanced Mine Detection System
ANS	Autonomous Navigation System
AP	Anti-Personnel Mine(s)
APD	Autonomous Platform Demonstrator
APM	Assistant Project Manager
APU	Auxiliary Power Unit
ARCIC	Army Capabilities Integration Center
ARFORGEN	Army Force Generation
ARL	Army Research Laboratory
ARM	Autonomous Robotic Manipulation
ARSOF	Army Special Operation Forces
ASA(ALT)	Assistant Secretary of the Army for Acquisition, Logistics and Technology
ASMO	Army Spectrum Management Office
ATEC	Army Test and Evaluation Command
ATO	Army Technology Objectives
ATO-D	Army Technology Objective - Demonstrator
ATO-M	Army Technology Objective - Manufacturing
..... B	
BCA	Business Case Analysis
BCIT	Brain Computer Interaction Technologies
BMO	Business Management Office
..... C	
C ²	Command and Control
CAM	Camera Arm Manipulator
CAMS	Combat Autonomous Mobility System
CAN	Cognition and Neuro-ergonomics
CASCOM	Combined Arms Support Command
CAST	Convoy Active Safety Technology
CBRN	Chemical, Biological, Radiological and Nuclear
CCD	Charged Coupled Device
CDD	Capability Development Document
CDL	Common Data Link
CDR	Critical Design Review
CENTCOM	US Central Command
CERDEC	Communications-Electronics Research Development & Engineering Center
C-IED	Counter Improvised Explosive Device
CMMI	Command Maintenance Management Inspection
CMOS	Complimentary Metal Oxide Semiconductor
CMP	Common Mobility Platform
CoE	Center(s) of Excellence

UNCLASSIFIED

COE	Common Operating Environment
COFDM	Coded Orthogonal Frequency Division Modulation
COLTS	Catalog Ordering Logistics Tracking System
COMSEC	Communications Security
CONOPS	Concept of Operations
CONUS	Contiguous United States
COTS	Commercial-off-the-Shelf
CoV	Class of Vehicle(s)
CPD	Capability Production Document
CR	Cognitive Radio
CRADA	Cooperative Research and Development Agreement
CREW	Counter Remote Control Improvised Explosive Device Electronic Warfare
CTA	Collaborative Technology Alliance
CWP	Coalition Warfare Project

D

DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DDL	Digital Data Link
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities

E

E ³	Electromagnetic Environmental Effects
EO/IR	Electro-Optical/Infrared
EOD	Explosive Ordnance Disposal
EOR	Element of Response
E-TESS	Electronic – Tactical Engagement Simulation System

F

FORSCOM	United States Army Forces Command
FoS	Family of Systems
FoV	Field of View
FUE	First Unit Equipped
FY	Fiscal Year

G

GHz	Giga Hertz
GIG	Global Information Grid
GPS	Global Positioning System
GUI	Graphic User Interface

H

H	Height, Horizontal
HBCT	Heavy Brigade Combat Team
HMI	Human/Machine Interface
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HMS	Handheld/Manpack/Small Form Fit
hp	Horsepower
HQDA	Headquarters, Department of the Army
HRED	Human Research Engineering Directorate
HRI	Human Robot Interaction
Hrs	Hours

Hz..... Hertz

..... **I**

IAW In Accordance With
 IBCT Infantry Brigade Combat Team
 ICD Initial Capabilities Document
 ICE Internal Combustion Engine
 IED Improvised Explosive Device(s)
 IEEE Institute of Electrical and Electronics Engineers
 IETM Interactive Electronic Technical Manual
 IMOPAT Improved Mobility and Operational Performance through Autonomous Technologies
 IMS Intelligent Munitions Systems
 INS Inertial Navigation System
 IOC Initial Operating Capability
 IOP Interoperability Profiles
 IOT Initial Operational Test
 IOT&E Initial Operational Test and Evaluation
 IP Internet Protocol
 IPM Imaging Perception Module
 IPT Integrated Product Team
 IR Infrared
 ISR Intelligence, Surveillance, and Reconnaissance

..... **J**

JAUS Joint Architecture for Unmanned Systems
 JCIDS Joint Capabilities Integration and Development System
 JCTD Joint Capability Technology Demonstration
 JGRE Joint Ground Robotics Enterprise
 JGRIT Joint Ground Robotic Integration Team
 JIEDDO Joint IED Defeat Organization
 JROC Joint Requirements Oversight Counsel
 JRRD Joint Robotic Repair Detachment(s)
 JRRF Joint Robotics Repair and Fielding Activity
 JTRS Joint Tactical Radio System
 JUONS Joint Urgent Operational Needs Statement(s)

..... **K**

kW Kilowatt
 kph Kilometers per hour

..... **L**

L Length
 LADAR Laser Detection and Ranging
 LAGR Learning Applied to Ground Robots
 Lbs pounds
 LED Light Emitting Diode
 LIDAR Light Detection and Ranging
 LIPM LADAR Imaging Perception Module
 LNO Liaison Officer
 LOS Line of Sight
 LRM Line Replaceable Module
 LRU Line Replaceable Unit
 LS3 Legged Squad Support System

.....	M
m	Meter
M&S	Modeling and Simulation
MAGIC	Multi Autonomous Ground-robotic International Challenge
MANET	Mobile Ad-Hoc Network
MARCORSYSCOM	Marine Corps Systems Command
MAST	Micro Autonomous Systems and Technology
MBT	Main Battle Tank
MCCDC	Marine Corps Combat Development Command
MCoE	Maneuver Center of Excellence
MCSC	Marine Corps Systems Command
MCWL	Marine Corps Warfighting Laboratory
MDA	Milestone Decision Authority
MDD	Milestone Documentation Decision
MGRS	Military Grid Reference System
MGV	Manned Ground Vehicle
MIMO	Multi Input Multi Output
Min	Minutes
MM-UGV	Multi-Mission Unmanned Ground Vehicle
MMWR	Millimeter Wave Radar
MOCU	Multi-Robot Operator Control Unit
MOLLE	Modular Lightweight Load-carrying Equipment
MOS	Military Occupational Specialty
MOUT	Military Operations in Urban Terrain
mph	Miles per Hour
MRAP	Mine Resistant Ambush Protected
MS	Milestone
MSCoE	Maneuver Support Center of Excellence
MTT	Mobile Training Teams
MUA	Military Utility Assessment

.....	N
NATO	North Atlantic Treaty Organization
NAUS	Near Autonomous Unmanned Systems
NAVEODTECHDIV	Naval EOD Technology Division
NDI	Non-Developmental Item
NIR	Near Infrared
NLOS	Non-Line of Sight
NLOS-LS	Non Line of Sight Launch System
NSA	National Security Agency

.....	O
OCO	Overseas Contingency Operations
OCONUS	Outside the Continental United States
OCU	Operator Control Unit
ODIS	Omni-Directional Inspection System
OEF	Operation Enduring Freedom
OEM	Original Equipment Manufacturer(s)
OFDM	Orthogonal Frequency Division Multiplexing
OIF	Operation Iraqi Freedom
OIPT	Overarching Integrated Product Team
OMA	Operations and Maintenance - Army
OND	Operation New Dawn

UNCLASSIFIED

ONS Operational Needs Statement(s)
 OPTEMPO Operational Tempo
 OSD Office of the Secretary of Defense
 OSRVT One System Remote Video Terminal

P

PATCM Product Assurance Test and Configuration Management
 PBL Program Base Line
 PC Personal Computer
 PCC Portable Computer Console
 PdM Product Manager
 PDREP Product Deficiency Reporting and Evaluation Program
 PEO C3T Program Executive Office – Command, Control and Communications - Tactical
 PEO GCS Program Executive Office Ground Combat Systems
 PEO-I Program Executive Office – Integration
 PEP Process Excellence Program
 PETN Pentaerythrite Tetranitrate
 PI Product Integrator
 PM Program Manager(s)
 POM Program Objective Memorandum
 POR Program(s) of Record
 PQDR Product Quality Deficiency Report

R

R&D Research and Development
 R2C Route Reconnaissance and Clearance Robot
 RADAR Radio Detection and Ranging
 RAI Rapid Acquisition Initiatives
 RAMAN Regional Atmospheric Measurement and Analysis Network
 RC Route Clearance
 RCIED Remote Control IED
 RDECOM Research, Development and Engineering Command
 RDS Robotics Deployment System
 RDT&E Research, Development, Test and Evaluation
 RDX Hexahydro-Trinitro-Triazine
 REF Rapid Equipping Force
 RF Radio Frequency
 RFI Radio Frequency Interference
 RFP Request for Proposal
 RIK Robotic Intelligence Kernel
 ROS Robotic Operating System
 RS JPO Robotic Systems Joint Project Office
 RSIL Robotic System Integration Lab

S

S&T Science and Technology
 SA Situational Awareness
 SAE Society of Automotive Engineers
 SAM Short Arm Manipulator, Situational Awareness Mast
 SANDI Supervised Autonomy to Neutralize and Detect IEDs
 SANGB Selfridge Air National Guard Base
 SBCT Stryker Brigade Combat Team
 SBIR Small Business Initiative Research

SC	Safety Confirmation
SCoE	Support Center of Excellence
SDD	System Development and Demonstration
SDR	Software Defined Radio
SDT	Second Destination Transportation
SE	System Engineer
SME	Subject Matter Expert
S-MET	Squad Multi-Purpose Equipment Transport
SMI	Soldier – Machine Interface
SMSS	Squad Mission Support System
SOC	Special Operations Command
SOFC	Solid Oxide Fuel Cell
SONAR	Sound Navigation and Ranging
SoSCOE	System of Systems Common Operating Environment
SOURCE	Safe Operations of Unmanned Systems for Reconnaissance in Complex Environments
SPAWAR	Space and Naval Warfare Systems Command
SQA	Software Quality Assurance
SRSUV	Squad Robotic Support Utility Vehicle
STANAG	Standardization Agreement
SU	Situational Understanding
SUGV	Small Unmanned Ground Vehicle
SWaP	Size, Weight and Power

..... **T**

TAC	Transportation Account Code
TARDEC	Tank and Automotive Research, Development and Engineering Center
TDP	Technical Data Package
TNT	Trinitrotoluene
TPE	Theater Provided Equipment
TRADOC	Training and Doctrine Command
TRL	Technology Readiness Level
TTP	Tactics, Techniques and Procedures

..... **U**

UAM	Universal Antenna Mount
UAP	User Assist Package
UAS	Unmanned Aircraft System(s)
UAV	Unmanned Aerial Vehicle
UGCV	Unmanned Ground Combat Vehicle
UGS	Unmanned Ground System(s)
UGV	Unmanned Ground Vehicle(s)
UMS	Unmanned Systems
USASFC	United States Army Forces Command
USASOC	United States Army Special Operations Command
USMC	United States Marine Corps
UWB	Ultra-Wideband

..... **V**

V	Vertical
VICTORY	Vehicular Integration for C4ISR/EW Interoperability
VOIED	Victim Operated IED
VSIL	Virtual System Integration Lab

.....	W
W	Watt, Width
W/kg	Watts per Kilogram
W/L	Watts per Liter
WARVVS	Wide Angle Robotic Vehicle Vision System
W-hr/kg	Watt Hours per Kilogram
W-hr/L	Watt Hours per Liter
WIN-T	Warfighter Information Network- Tactical
WIPT	Working Integrated Product Team
WLAN	Wireless Local Area Network
WNaN	Wireless Network After Next



Unmanned Systems Integrated Roadmap

FY2011-2036

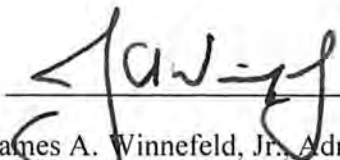


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THE UNMANNED SYSTEMS INTEGRATED ROADMAP
FY2011-2036



James A. Winnefeld, Jr., Admiral, USN
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Acting Under Secretary of Defense
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EXECUTIVE SUMMARY

U.S. and allied combat operations continue to highlight the value of unmanned systems in the modern combat environment. Combatant Commanders (CCDRs) and warfighters value the inherent features of unmanned systems, especially their persistence, versatility, and reduced risk to human life. The U.S. military Services are fielding these systems in rapidly increasing numbers across all domains: air, ground, and maritime. Unmanned systems provide diverse capabilities to the joint commander to conduct operations across the range of military operations: environmental sensing and battlespace awareness; chemical, biological, radiological, and nuclear (CBRN) detection; counter-improvised explosive device (C-IED) capabilities; port security; precision targeting; and precision strike. Furthermore, the capabilities provided by these unmanned systems continue to expand.

The Department of Defense (DoD) has been successful in rapidly developing and fielding unmanned systems. DoD will continue to focus on responding rapidly to CCDR requirements, while ensuring systems are acquired within the framework of DoD's new wide-ranging Efficiencies Initiatives¹. In the fiscal environment facing the Nation, DoD, in concert with industry, must pursue investments and business practices that drive down life-cycle costs for unmanned systems. Affordability will be treated as a key performance parameter (KPP) equal to, if not more important than, schedule and technical performance. DoD will partner with industry to continue to invest in unmanned systems technologies while providing incentives for industry to implement cost-saving measures and rewarding industry members that routinely demonstrate exemplary performance.

My Acquisition Decision Memorandum (ADM) approving formal program commencement of the program will contain an affordability target to be treated by the Program Manager like a Key Performance Parameter (KPP) such as speed, power, or data rate

—Under Secretary of Defense Memorandum for Acquisition Professionals, Better Buying Power, September 2010¹

This document provides a DoD vision for the continuing development, fielding, and employment of unmanned systems technologies. Since publication of the last DoD Roadmap in 2009, the military Services have released individual Service roadmaps or related strategy documents. This roadmap defines a common vision, establishes the current state of unmanned systems in today's force, and outlines a strategy for the common challenges that must be addressed to achieve the shared vision.

The challenges facing all military Services in the Department include:

- 1) Interoperability: To achieve the full potential of unmanned systems, these systems must operate seamlessly across the domains of air, ground, and maritime and also operate

¹ Better Buying Power, Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending, OUSD(AT&L) Memo, Dr. Ashton B. Carter, 14 September 2010.

seamlessly with manned systems. Robust implementation of interoperability tenets will contribute to this goal while also offering the potential for significant life-cycle cost savings.

- 2) **Autonomy:** Today's iteration of unmanned systems involves a high degree of human interaction. DoD must continue to pursue technologies and policies that introduce a higher degree of autonomy to reduce the manpower burden and reliance on full-time high-speed communications links while also reducing decision loop cycle time. The introduction of increased unmanned system autonomy must be mindful of affordability, operational utilities, technological developments, policy, public opinion, and their associated constraints.
- 3) **Airspace Integration (AI):** DoD must continue to work with the Federal Aviation Administration (FAA) to ensure unmanned aircraft systems (UAS) have routine access to the appropriate airspace needed within the National Airspace System (NAS) to meet training and operations requirements. Similar efforts must be leveraged for usage of international airspace.
- 4) **Communications:** Unmanned systems rely on communications for command and control (C2) and dissemination of information. DoD must continue to address frequency and bandwidth availability, link security, link ranges, and network infrastructure to ensure availability for operational/mission support of unmanned systems. Planning and budgeting for UAS Operations must take into account realistic assessments of projected SATCOM bandwidth, and the community must move toward onboard pre-processing to pass only critical information.
- 5) **Training:** An overall DoD strategy is needed to ensure continuation and Joint training requirements are in place against which training capabilities can be assessed. Such a strategy will improve basing decisions, training standardization, and has the potential to promote common courses resulting in improved training effectiveness and efficiency.
- 6) **Propulsion and Power:** The rapid development and deployment of unmanned systems has resulted in a corresponding increased demand for more efficient and logistically supportable sources for propulsion and power. In addition to improving system effectiveness, these improvements have the potential to significantly reduce life-cycle costs.
- 7) **Manned-Unmanned (MUM) Teaming:** Today's force includes a diverse mix of manned and unmanned systems. To achieve the full potential of unmanned systems, DoD must continue to implement technologies and evolve tactics, techniques and procedures (TTP) that improve the teaming of unmanned systems with the manned force.

This Roadmap leverages individual Service roadmaps and visions, and identifies challenges that might stand in the way of maturing those visions to a shared Joint vision. The vignettes provided at the beginning of the Roadmap give the reader a glimpse into potential unmanned systems capabilities. They do not serve as requirements—the individual Services will continue to identify requirements gaps and utilize the Joint Capabilities Integration and Development System (JCIDS) to determine which requirements to fund. The chapters that follow the vignettes identify core areas that are challenges for further growth in unmanned systems and chart out science, technology, and policy paths that will enable unmanned systems to fulfill an expanding role in

supporting the warfighter. Success in each of these areas is critical to achieve DoD's shared vision and realize the full potential of unmanned systems at an affordable cost.

... the ability to understand and control future costs from a program's inception is critical to achieving affordability requirements.

—Under Secretary of Defense Memorandum for Acquisition Professionals, Better Buying Power, September 2010¹

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1 INTRODUCTION/SCOPE

1.1 Purpose

The purpose of this document is to describe a vision for the continued integration of unmanned systems into the Department of Defense (DoD) Joint force structure and to identify steps that need to be taken to affordably execute this integration. DoD has seen rapid growth, sparked in large part by the demands of the current combat environment, in the development, procurement, and employment of unmanned systems. Today's deployed forces have seen how effective unmanned systems can be in combat operations. This experience has created expectations for expanding the roles for unmanned systems in future combat scenarios. This Roadmap establishes a vision for the next 25 years and outlines major areas where DoD and industry should focus to ensure the timely and successful adoption of unmanned systems.

1.2 Scope

This Roadmap follows the path originally laid out in the 2007 and 2009 Roadmaps in addressing all three unmanned domains: air, ground, and maritime. However, this document deviates from the earlier editions, primarily as a result of the following:

- An Unmanned Systems Roadmap survey conducted by the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics) (OUSD(AT&L))
- Publication of service-specific roadmaps for unmanned systems

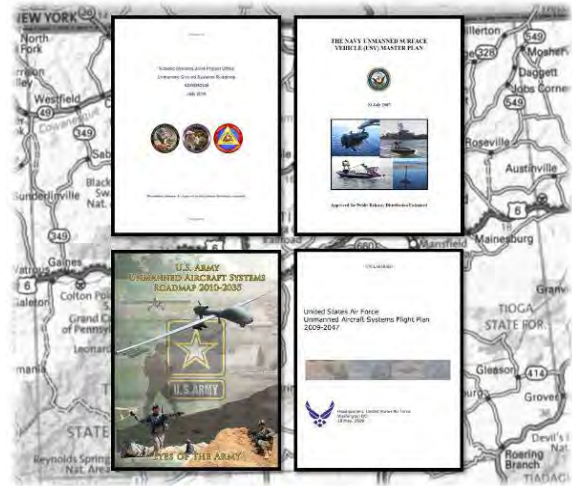
Shortly after the publication of the 2009 Roadmap, OUSD(AT&L) conducted a survey of key stakeholders and users of the Roadmap. The survey sampled a wide audience, including: Office of the Secretary of Defense (OSD), Service headquarters, warfighting commands, Service acquisition organizations, Service laboratories, multiple Joint organizations, other government agencies, industry (both large and small businesses), and academia. One of the major outcomes of this survey was a decision to capture the catalog function of the Roadmap in a separate, online tool. The reason for this decision is that the online tool provides greater functionality than that of the two-dimensional, hard-copy catalog, including the capability for more frequent updates than the biennial printed Roadmap. The catalog can be found on the Unmanned Warfare Information Repository site at: <https://extranet.acq.osd.mil/uwir/>.

The survey also helped define the audience for the 2011 edition. This Roadmap provides a common vision and problem set to help shape military Service investments. The document also describes DoD's direction to help industry participants shape their investments, particularly with respect to independent research and development.

Since the publication of the 2009 Roadmap, each military Service has developed its own roadmap or equivalent document (listed in Appendix A). The U.S. Air Force (USAF) released its "Unmanned Aircraft Systems Flight Plan" in 2009 outlining an actionable plan across the diverse spectrum of doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P). In 2009, the U.S. Army published the "Unmanned Ground Systems Roadmap," providing a common resource document for Army and U.S. Marine Corps (USMC) stakeholders in unmanned ground vehicles (UGVs). The Army released its unmanned

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aircraft systems (UAS) Roadmap in 2010, which established a broad vision for developing, organizing, and employing UAS across the spectrum of Army operations. In November 2009, the USMC published its “Concept of Operations for USMC Unmanned Aircraft Systems Family of Systems (CONOPS for USMC UAS FoS).” Finally, the U.S. Navy published its “Information Dominance Roadmap for Unmanned Systems” in December 2010. In light of these recent publications (see right), this Roadmap was tailored to focus on common issues facing all Services as well as to articulate a vision for achieving these goals in today’s fiscal environment. The goal for this document is to serve as a single, unified source to clearly articulate the DoD common vision for unmanned systems and to identify a common problem set facing DoD in maximizing the military utility offered by these versatile and innovative systems.



2 VISION

The Department of Defense's vision for unmanned systems is the seamless integration of diverse unmanned capabilities that provide flexible options for Joint Warfighters while exploiting the inherent advantages of unmanned technologies, including persistence, size, speed, maneuverability, and reduced risk to human life. DOD envisions unmanned systems seamlessly operating with manned systems while gradually reducing the degree of human control and decision making required for the unmanned portion of the force structure.

... to ensure safe, effective and supportable capabilities are provided while meeting cost, schedule and performance. The parallel vision is to provide continuous improvement of unmanned system capabilities to meet current and future Warfighter objectives.

– *Mission and Vision, Robotic Systems Joint Project Office Unmanned Ground Systems Roadmap, July 2009*

... develop and field cost-effective USVs to enhance Naval and Joint capability to support: Homeland Defense, the Global War on Terror, Irregular Warfare, and conventional campaigns.

– *The USV vision, The Navy Unmanned Surface Vehicle Master Plan, 23 July 2007*

... adopt innovative strategies to provide cost effective logistical support ...

– *Goals and Objectives, US Army Roadmap for UAS 2010-2035*

... to harness increasingly automated, modular, globally connected, and sustainable multi-mission unmanned systems resulting in a leaner, more adaptable and efficient Air Force that maximizes our contribution to the Joint Force.

– *USAF vision, USAF Unmanned Aircraft Systems Flight Plan 2009-2047*

2.1 Future Operational Environment

The strategic environment and the resulting national security challenges facing the United States for the next 25 years are diverse. The United States faces a complex and uncertain security landscape in which the pace of change continues to accelerate. The rise of new powers, the growing influence of nonstate actors, the spread of weapons of mass destruction and other irregular threats, and continuing socioeconomic unrest will continue to pose profound challenges to international order.

Over the next two decades, forces will operate in a geostrategic environment of considerable uncertainty with traditional categories of conflict becoming increasingly blurred. This era will be characterized by protracted confrontation among state, nonstate, and individual actors using violent and nonviolent means to achieve their political and ideological goals. Future adversaries will rely less on conventional force-on-force conflicts to thwart U.S. actions and more on tactics that allow them to frustrate U.S. intentions without direct confrontation.

The future operating environment will be one of constant and accelerating change. Economic, demographic, resource, climate, and other trends will engender competition locally, regionally, and globally.... State and non-state actors will find new and more deadly means of conducting operations in all domains, to include land, air, maritime, and cyberspace to further their aims ... otherwise leveraging land, air, and maritime areas to ensure their freedom of movement and deny it to others..

– *Joint Operational Concept, Irregular Warfare: Countering Irregular Threats*

As technological innovation and global information flows accelerate, nonstate actors will continue to gain influence and capabilities that, during the past century, remained largely the purview of states. Chemical and biological agents will become increasingly more accessible, lethal and sophisticated. Both state and nonstate actors will actively pursue nuclear weapons, sophisticated and/or bioengineered biological agents, and nontraditional chemical agents.

The next quarter century will challenge U.S. Joint Forces with threats and opportunities ranging from regular and irregular wars in remote lands, to relief and reconstruction in crisis zones, to cooperative engagement in the global commons There will continue to be opponents who will try to disrupt the political stability and deny free access to the global commons that is crucial to the world's economy.... In this environment, the presence, reach, and capability of U.S. military forces, working with like-minded partners, will continue to be called upon to protect our national interests.

– *Joint Operating Environment 2010: Ready For Today, Preparing For Tomorrow*

Unmanned systems can help in countering these threats by reducing risk to human life and increasing standoff from hazardous areas.

2.2 DoD's Vision

The DoD, along with industry, understands the effect that innovation and technology in unmanned systems can have on the future of warfare and the ability of the United States to adapt to an ever-changing global environment. DoD and industry are working to advance operational concepts with unmanned systems to achieve the capabilities and desired effects on missions and operations worldwide. In building a common vision, DoD's goals for unmanned systems are to enhance mission effectiveness, improve operational speed and efficiency, and affordably close warfighting gaps.

DoD is committed to harnessing the potential of unmanned systems and strengthening mission effectiveness while maintaining fiscal responsibility. DoD will also work on establishing a complementary relationship between manned and unmanned capabilities while optimizing commonality and interoperability across space, air, ground, and maritime domains.

Open architecture (OA) and open interfaces need to be leveraged to address problems with proprietary robotic system architectures. Standards and interface specifications need to be established to achieve modularity, commonality, and interchangeability across payloads, control systems, video/audio interfaces, data, and communication links. This openness will enhance competition, lower life-cycle costs, and provide warfighters with enhanced unmanned capabilities that enable commonality and joint interoperability on the battlefield.

By prudently developing, procuring, integrating, and fielding unmanned systems, DoD and industry will ensure skillful use of limited resources and access to emerging warfighting capabilities. Pursuing this approach with unmanned systems will help DOD sustain its dominant global military power and provide the tools required by national decision-makers to influence foreign and domestic activities while adapting to an ever-changing global environment. The following quotation captures the breadth of the challenge:

I speak for the Navy, that unmanned systems have to address all of the domains in which the Navy operates.... We operate on the surface, above the surface, into space, but then we operate below the surface. So when we talk about unmanned and ... as we knit all of this capability together and capacity together, it has to take into account that we're operating in all those different domains.

– Admiral Gary Roughead, Chief of Naval Operations (CNO)

With the current fiscal environment of constrained budgets, affordability is a factor across the entire acquisition cycle and must be actively engaged by the program managers, users, trainers, and testers to identify problems early, and address cost throughout the life cycle. A dollar saved early results in hundreds of saved dollars compared to problems resolved in production or worse yet during operations and support. While “open systems architecture and data rights” are critical to keeping costs in check, emphasizing the removal of obstacles to competition and the

opportunities in test and evaluation (T&E) to facilitate competitive analysis is equally important to reduce developmental costs.

The assembly line of activity involved in producing unmanned systems must address risk across the life cycle to address the new challenges of testing autonomous functionality in the initial stages, and evaluating the operation and support issues involved in sustainment for increasing reliability, availability, and maintainability. The emphasis on vignettes at a mission level only indirectly emphasizes the increasing need for an evolutionary capability in unmanned systems production that is resilient and responsive to the dynamic situation faced by today's warfighter. New technology, methodologies, and human resourcing are critical for establishing rapid acquisition environments that maximize the potential for unmanned systems production.

2.3 Vignettes

The following vignettes offer examples of the increased capability and flexibility inherent in unmanned systems as DoD continues to field unmanned technologies and integrate resulting systems into its existing force structure. These vignettes are not intended to present an exhaustive list of the possibilities, but rather to present a few examples to illustrate the vision described throughout this Roadmap.

2.3.1 Interoperability Across Domains Vignette, 2030s

Location: Northern Pacific Littoral Areas

Situation: The number and boldness of coordinated, provocative efforts between the Republic of Orangelandia (ROO) and the increasing number of radicalized Islamic nation-states within the tropic zones ($\pm 20^\circ$ latitude) have increased over the past 15 years. ROO has demonstrated a delivery capability for nuclear intercontinental ballistic missiles, and several radical Islamic nations now openly possess nuclear weapon technology. Although nuclear power's role is expanding, oil remains the energy resource of preference even though gaining access to oil by Western nations has become increasingly constrained and expensive. The United States' gross domestic product (GDP) is being challenged by China.

Scenario: A 50-year-old, former Soviet-era, *Akula* class, nuclear-powered attack submarine sails out of ROO's Molan harbor at night unobserved by Western reconnaissance satellites. Movements of ROO submarines are of high interest due to their rarity (fewer than a dozen occurrences a year) and primarily due to ROO's status as a rogue, nuclear-capable nation-state. The submarine's departure is detected by the underwater surveillance grid, which is monitoring vessel movements in and out of the ROO waters. Ahead of the submarine, a glider unmanned underwater vehicle (UUV) is autonomously



detached from the local network to intercept the faster submarine. Closing to within 50 yards as the submarine passes, the UUV succeeds in attaching a tether to the submarine, which begins pulling the UUV along (see figure right). As the submarine dives below the UUV's operating depth, the UUV adjusts the tether to maintain its position close to the surface. Every three hours, it glides to the surface and transmits a low-power position report.

The position reports are received by an orbiting communications relay, Baton One, an EQ-25 UAS operating at 75,000 ft in the eastern Pacific region. The EQ-25 is an extreme-endurance UAS, capable of operating for two months on station without refueling. As the submarine enters the Sea of Okhotsk and heads toward the North Pacific Ocean, U.S. military commanders are faced with a decision. Despite the advanced battery technology of the UUV, the battery life is finite; therefore, the operators have three courses of action affecting their surveillance operation: (1) continue surveillance by shifting the orbit of Baton One to maintain reception range on the UUV, which will otherwise be lost in 12 hours (2) save the UUV by detaching it when its remaining power is still sufficient for it to recover itself (within three days) or (3) expend the UUV by keeping it attached until its power is exhausted (within six days). Because ROO submarines seldom sortie beyond the littoral seas of northeastern Asia, they decide to shift Baton One's orbit and wait to decide the UUV's fate until the submarine's intent becomes clearer.

By the third day, the submarine is heading toward the mid-Pacific and the Hawaiian Islands. Because the value of the mission exceeds the cost of the asset, the decision is made to expend the low-cost UUV to buy time for a naval anti-submarine warfare (ASW) ship to intercept and track the submarine. The following day, the submarine reverses course. Two days later, the still-attached UUV converts to beacon mode to conserve its dwindling power reserves, Baton One returns to its planned orbit, and the ASW ship turns for Pearl Harbor. A Broad Area Maritime Surveillance (BAMS) UAS, MQ-4C, is launched from Guam to track the beacon. It recovers the beacon's signal and determines that it is stationary. Autonomously descending with its internal airborne sense and avoid (ABSAA) system to maintain "due regard," the BAMS UAS is able to visually acquire the UUV, floating in mid-ocean and no longer attached to the ROO submarine — potentially detached by the submarine's crew. The submarine's position and intent are now unknown.

Ten days later, a weak seismic disturbance is detected 150 miles southeast of Anchorage, Alaska (see map below). Several minutes later, a much more significant event registers 3.5 on the Richter scale. An interagency DoD/homeland defense reconnaissance UAS is launched out of Elmendorf Air Force Base (AFB) and detects a radiation plume emanating near Montague Island at the mouth of Prince William Sound. The UAS maps the plume as it begins spreading over the sound, and a U.S. Coast Guard offshore patrol cutter deployed from Kodiak employs its



embarked unmanned helicopter to drop buoys with chemical, biological, radiological, and nuclear (CBRN) sensors in the Sound and within narrow passes to measure fallout levels. The plume begins to spread over the sound and threatens the city of Valdez. All vessel traffic, mainly oil tankers, transiting in and out of the Sound is stopped, and operations at the oil terminal are suspended. Oil storage facilities at the terminal are quickly filled to capacity, and the flow from Prudhoe Bay is shut down. The port of Valdez, the largest indigenous source of oil for the United States, is effectively under quarantine.

Due to the growing contamination of the local environment, disaster response officials decide to request the support of the military because of their experience both with operations in CBRN zones and with unmanned systems, which are the tools of choice because of the contamination hazards to personnel. The amphibious transport dock ship USS *New York* anchors near an entrance to Prince William Sound and begins operations with its unmanned surface vehicles (USVs) and MQ-8 detachments. An EQ-25 orbit is established over the Sound to ensure long-term, high-volume communication capability in the high-latitude, mountainous region. With data compression technology fielded in the transmitting and relay systems, the EQ-25 is capable of handling all the theater data relay requirements. A USV proceeds to the focus of contamination and lowers a tethered remotely operated vehicle (ROV) to conduct an underwater search for the source. The USV's sonar quickly locates a large object in very shallow water and, on closer inspection by the ROV, images the severely damaged hull of what appears to be an *Akula* class submarine. The hull is open to the sea, and the ROV places temperature gradient sensors on the hull and inserts gamma sensors into the exposed submarine compartments. The Joint Task Force that was formed to manage the disaster quickly determines that the reactor fuel core is exposed to the sea and that the reactor was not shut down and is still critical. Suspicion of the submarine's origin centers on its being from ROO, but all evidence that this vessel is the lost *Akula* submarine is currently circumstantial.

The radiation plume has now encompassed the evacuated town of Valdez, and MQ-8s fly repeated sorties to the town, dock, and terminal areas to deploy UGVs with sensors and collect samples for analysis. Returning USVs and MQ-8s are met and serviced by personnel in hazmat gear and washed down after each sortie. With conditions deteriorating, two unmanned Homeland Defense CBRN barges fitted with cranes, containers, and remote controls arrive from Seattle. USVs are stationed in the narrow straits leading into the Sound with hydrophones to broadcast killer whale sounds to frighten fish outside the Sound away from the contaminated area. Over the next two weeks, with the assistance of U.S. and coalition ROVs equipped with cutting torches, grappling fixtures, and operating from USVs, one remotely operated submersible barge is able to work around the clock with impunity against exposure levels to recover the exposed fuel sources and to isolate them in specially designed containers. A second barge similarly retrieves sections of the crippled submarine. Both barges operate with a high degree of autonomy, limiting exposure of personnel to the radioactive contamination.

The UGVs continue monitoring contamination levels and collecting samples, but now also start conducting decontamination of the oil terminal control station and the local power and water facilities. Highly contaminated soil is placed into steel drums, and larger UGVs are used to dig pits and bury contaminated building and pipeline materials. Advanced sensor technology and control logic allows the UGVs to operate around the clock with human operators serving solely in a monitoring function. USVs are used to collect carcasses floating in the Sound and bring

them to shore for disposal. UUVs crisscross the seafloor of the Sound to locate and tag remnants of the submarine for later collection. Unmanned aircraft (UA) fly continuously through the National Airspace System (NAS) at low altitude to monitor and map the declining radiation contours, at medium altitude to map cleanup operations, and at high altitude to relay control commands and data from the nearly one hundred unmanned vehicles at work. Decontamination, refueling, and repair shops have been established in nearby Cordova to service the vehicles and aircraft and on the USS *New York* to service the boats and submersibles. It is the largest coordinated use of international air, ground, and maritime unmanned systems ever conducted.

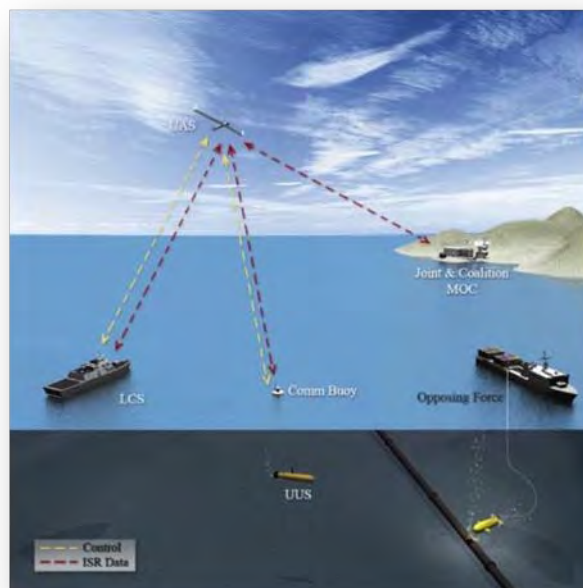
2.3.2 African Maritime Coalition Vignette, 2030s

Location: Gulf of Guinea off the coast of Africa

Situation: An UAS and an UUV, deployed from littoral combat ship (LCS) *Freedom*, are on patrol monitoring the littoral oil infrastructure of a developing nation-state. This nation-state has recently adjusted its geopolitical stance to ally itself militarily and economically with the United States and friendly European governments.

Scenario: The *Freedom*'s UUV in its assigned patrol area detects an anomaly, a remote pipeline welder controlled by an unknown force. The underwater remote welder is positioning itself to intersect a major underwater oil pipeline. Using its organic "smart software" processing capability, the UUV evaluates the anomaly as a possible threat and releases a communications buoy that transmits an alert signal and a compressed data "snapshot" from the UUV's onboard video/acoustic sensor.

The communications buoy's low probability of intercept (LPI) data are relayed via a small tactical unmanned aircraft system (STUAS) to other units in the area and to the Joint Maritime Operations Center (JMOC) ashore. The commander on the LCS directs the UUV and the UAS to provide persistent intelligence, surveillance, and reconnaissance (ISR) and command and control (C2) relay support. Simultaneously, the UAS transmits corroborating ISR data on a suspect vessel near the UUV anomaly. Thanks to a recently fielded, advanced technology propulsion upgrade, the STUAS is able to stay on station for 24 hours before being relieved (see graphic right).



Meanwhile, the JMOC analysts recognize the pipeline welder in the UUV data snapshot as one recently stolen and acquired by rebel antigovernment forces. The JMOC then dispatches an Allied quick reaction force (QRF) via 160th Special Operations Aviation Regiment (SOAR) aircraft and USAF CV-22 Osprey from a nearby airfield. The JMOC retasks a special warfare combatant-craft crewman (SWCC) Mk V to

investigate and neutralize the potential hostile surface vessel controlling the stolen pipeline welder. The SWCC Mk V launches its own small UA to provide a low-level ISR view ahead of its navigation track while providing an LPI secure communications path among the special forces QRF team. The SWCC Mk V's UA provides a real-time common data link (CDL) common operational picture (COP) data stream via the higher altitude UAS to the LCS and JMOC.

The JMOC receives a signals intelligence (SIGINT) alert that the suspect hostile surface vessel is launching a Russian Tipchak, a medium-altitude, long-endurance (MALE) UA. The latest Tipchak variant is a hybrid UA with US-derived systems and avionics. This Tipchak is capable of launching short-range air-to-air missiles (AAMs) or air-to-surface missiles (ASMs). Its host platform, the suspect hostile vessel, has an early warning suite and has probably detected the LCS nearby or visually sighted the SWCC Mk V's UA. An update to the SIGINT alert at the JMOC reveals the Tipchak is being launched for a surveillance sweep and counter-air/counter-UA mission.

Realizing the hostile UA could pose a risk or even jeopardize the QRF, the JMOC commander launches a USAF MQ-1000 UA optimized for air interdiction and ground strike. The MQ-1000 UA, empowered by rules of engagement (ROE) allowing autonomous operation, immediately conducts an air-to-air engagement and neutralizes the Tipchak UA.

The SWCC Mk V's special forces team then conducts a visit, board, search, and seizure (VBSS) on the suspected hostile vessel supporting the UUV pipeline interdictor. Since the threat is neutralized, the unmanned systems update their patrol status, cancel the alert status, and recover or resume their assigned patrol sectors.

2.3.3 Complex Unmanned Systems Test and Evaluation Scenario

As unmanned systems become more complicated, more integrated, more collaborative, and more autonomous, establishing test-driven development constructs and infrastructure for supporting early-onset test and evaluation (T&E) and life-cycle T&E will become increasingly

"The key to successful acquisition programs is getting things right from the start with sound systems engineering, cost estimating, and developmental testing early in the program cycle. The bill that we are introducing today will require the Department of Defense to take the steps needed to put major defense acquisition programs on a Sound footing from the outset. If these changes are successfully implemented, they should help our acquisition programs avoid future cost overruns, schedule delays, and performance problems."

—Senator Carl Levin, Chairman, Senate Armed Services Committee

"The Weapon System Acquisition Reform Act of 2009 is an important step in efforts to reform the defense acquisition process. This legislation is needed to focus acquisition and procurement on emphasizing systems engineering; more effective upfront planning and management of technology risk; and growing the acquisition workforce to meet program objectives."

—Senator John McCain, Ranking Member, Senate Armed Services Committee

critical. The Weapon Systems Acquisition Reform Act (WSARA) of 2009 sets the stage for

advancing T&E that will address cost saving through early-on engagement and effective sustainment in facilitating unmanned systems acquisition.

The two previous vignettes have focused on the utility of unmanned systems, but it is also helpful to focus on unmanned systems acquisition. The acquisition of systems with increasing net-centricity and automated functionality will introduce unexpected levels of risk. Systems engineering involves decomposing a design into separable elements, characterizing the intended relationships between them, and verifying the system built to specification operates as intended. The systems engineering “V” represents decomposition and design on the downstroke and integration, verification, and validation on the upstroke. As systems become more complex, the difficulties of addressing the upstroke of the “V” increase. T&E is critical for addressing this risk. The systems engineering of complex systems is gets scrutinized when major problems lead to program delays, cost overruns, and even cancellations. The issues typically lie with unintended and unanticipated interactions between elements that are uncovered only during integration, testing, or once in service. The T&E of manned systems has created optimal strategies for reducing risk in the areas of frequency, performance, support systems, and safety. The primary challenge for today’s defense acquisition system is to execute acquisition programs without major schedule delays and cost overruns. Meeting that challenge has been the goal of acquisition reform improvements for decades.

Unmanned systems raise new issues of artificial intelligence, communications, autonomy, interoperability, propulsion and power, and manned-unmanned (MUM) teaming that will challenge current T&E capabilities. These problems will get more serious as systems become more interactive and more automated. Failures often occur at the interfaces between system elements, in many cases, between interfaces thought to be separate. The exponential trends in software and network communications increasingly mean that many elements of a system can now affect one another. The incredible complexity of millions of lines of software requires new approaches for detecting problems earlier in the design phase where cost mitigation is most effective. As systems get much of their functionality from software and multisystem interactions, complexity is no longer separate and distinct. Complexity is about the whole ecosystem, and systems engineering has to become more holistic. Model-based systems engineering, already in use by the software and circuit industries, is augmenting document-driven approaches in important ways. Executable models can be effective conveyors of information throughout a supply chain. Models designed to provide contextual information about the degrees of freedom and the interactions could potentially pass from the Government to the prime supplier and on to second- and third-tier suppliers from early concept through Milestones A, B, and C into the operations and support phase.

Location: DoD T&E Centers Across the World

Situation: In a rapid acquisition support environment, integrated T&E teams work with trainers and the user to accelerate the production of unmanned systems. The model involves industries that must leverage test frameworks to take advantage of Moore’s Law advances that are exploitable every 18 months. The same technologies are actually subcomponents in the payload, communication, command system, and remote sensor support systems that currently compose various unmanned system of systems configurations.

Scenario: Warfighters need next-generation system capability to support an 18-month battlespace fielding requirement. The system involves new sensors supporting a remote sensor team. The platform will utilize several new algorithms to mitigate human support functions limited by human reaction time and communication anomalies. The platform will also have new decision algorithms supporting mission functions due to new payload capabilities. The system will use a new communication protocol evaluation system for onboard teams and for ground control teams communicating over a series of relay station and satcom grids. Platform support includes mission-driven T&E to validate autonomous support capabilities enabling nonlethal support functions. This migration will use technology for air traffic management that the Federal Aviation Administration (FAA) and DoD are co-evaluating for the automated notification of an aircraft's position to ground-based controllers as well as to other manned and unmanned aircraft.

The support situation calls for an assessment of the latest Standardization Agreement (STANAG) recovery algorithms in the event of communications link disruption with collaborating manned and unmanned systems supporting a teaming operation. Interoperability tests will be necessary to support several new services and remote service support teams translating data from the payload. The teams will leverage mission information from a variety of semantic databases across the Defense Grid to generate actionable intelligence. A new aspect of this deployment will involve the utilization of both trainers and users interacting with simulators to explore the adequacy of human systems integration algorithms to discover problems for algorithm refinement and problem discovery. Red team T&E technology will expand scenario assessment to provide forecasting without historical data using Bayesian probability models utilizing expert opinions. The T&E system will be designed to determine false positives, false negatives, dynamic limits, and integrity limits regarding mission effectiveness, suitability, survivability, and effectiveness. This wholesale advancement in T&E will result in a tenfold reduction in cycle time and cost.

3 CURRENT STATE

Over the past decade, unmanned systems have played an increasing role in U.S. military operations. DoD uses a vast array of unmanned systems, from underwater to the upper regions of the atmosphere, from the size of a matchbox to the size of a Boeing 737.

These unmanned systems continue to prove their value in combat operations in Afghanistan, where military operations are planned and executed in extremely challenging environments. Adversaries are fighting using increasingly unconventional means, taking cover in the surrounding populations, and employing asymmetric tactics to achieve their objectives. In future conflicts, we must be prepared for these tactics as well as a range of other novel methods, including so-called “hybrid” and anti-access approaches to blunting U.S. power projection. Unmanned systems will be critical to U.S. operations in all domains across a range of conflicts, both because of capability and performance advantages, and the ability for unmanned systems to take greater risk.

As unmanned systems have proven their worth on the battlefield, DoD has allocated an increasing percentage of its budget to developing and acquiring these systems. Table 1 below reflects the budget request allocated to the three unmanned domains: air, ground, and maritime.

Table 1. 2011 President’s Budget for Unmanned Systems (\$ Mil)

Unmanned Funding (\$ Mil)							
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
Air	RDTE	1,106.72	1,255.29	1,539.58	1,440.57	1,296.25	6,638.40
	PROC	3,351.90	2,936.93	3,040.41	3,362.95	3,389.03	16,081.21
	OM	1,596.74	1,631.38	1,469.49	1,577.65	1,825.45	8,100.71
Domain Total		6,055.36	5,823.59	6,049.48	6,381.17	6,510.72	30,820.32
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
Ground	RDTE	0.00	0.00	0.00	0.00	0.00	0.00
	PROC	20.03	26.25	24.07	7.66	0.00	78.01
	OM	207.06	233.58	237.50	241.50	245.96	1,165.60
Domain Total		227.09	259.83	261.57	249.16	245.96	1,243.61
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
Maritime	RDTE	29.69	62.92	65.72	48.60	47.26	254.19
	PROC	11.93	45.45	84.85	108.35	114.33	364.90
	OM	5.79	4.71	3.76	4.00	4.03	22.28
Domain Total		47.41	113.08	154.32	160.94	165.62	641.37
Fiscal Year Defense Prog		FY11	FY12	FY13	FY14	FY15	Total
All Unmanned	RDTE	1,136.41	1,318.21	1,605.29	1,489.16	1,343.52	6,892.59
	PROC	3,383.86	3,008.63	3,149.32	3,478.96	3,503.36	16,524.12
	OM	1,809.59	1,869.67	1,710.75	1,823.15	2,075.44	9,288.59
Domain Total		6,329.86	6,196.50	6,465.36	6,791.27	6,922.31	32,705.30

Although unmanned systems have experienced widespread growth in funding, current world economic conditions and DoD initiatives necessitate increased efforts and focus toward the acquisition of affordable and convergent systems. DoD must continue to support diverse mission sets and capabilities, but must focus on acquiring Joint and interoperable platforms, systems, software, architecture, payloads and sensors due to today's increasingly austere fiscal environment. In addition, the ability for commanders to take risks with unmanned vehicles depends significantly on their cost. In order to be expendable, which is often the intent of building an unmanned system, the vehicle must be low-cost. The importance of procuring common platforms with core C2 systems cannot be overstated as it will yield enormous collective benefits by reducing training costs, reducing supply chain diversity, improving availability, and offering a cost-effective procurement path by exploiting the benefits of scale and software/technology reuse.

Eliminate redundancy within warfighter portfolios.

*—Under Secretary of Defense Memorandum for Acquisition
Professionals, Better Buying Power, September 2010*

The cost overruns, schedule slips, and sustainability issues of unmanned systems cannot go unnoticed or unanswered. Operational T&E is not sufficient for addressing budget, schedule, and sustainment issues in unmanned systems acquisition. WSARA 2009 guidance set the stage for leveraging developmental T&E as a key factor in T&E strategy to address Milestone A and B test challenges. Unmanned system T&E must not only consider physics effects but other areas that have an effect on algorithm development such as human factors, autonomous functionality, peering, collaboration, and autonomy-driven, red-team-based T&E limit testing. The goal to gradually reduce the degree of human control and decision making required for the unmanned portion of the force structure will mean that autonomous functionality will gradually increase and new ways to test this functionality will be required.

The need to maintain simplicity and overcome bureaucracy in unmanned system acquisition is an ongoing challenge. As these programs transition to acquisition programs, there is a unique opportunity to enable productive process and oversight appropriate to producing safe, suitable, survivable, and effective systems in a rapid acquisition framework.

There is a need to leverage OA and open interfaces to overcome the problems associated with proprietary robotic system architectures. Standards and interface specifications need to be established to achieve modularity, commonality, and interchangeability across payloads, control systems, video/audio interfaces, data, and communication links. Standardization will enhance competition, lower life-cycle costs, and provide warfighters with enhanced unmanned capabilities that enable commonality and joint interoperability on the battlefield.

Addressing factors inhibiting the growth of unmanned systems will provide more interoperability, more autonomy, better artificial intelligence, better communications, human systems integration, training standardization, more propulsion and power options, and better MUM teaming. These factors are addressed through the Joint Capability Integration and Development System (JCIDS) process.

3.1 Requirements Development and Systems Acquisition

There has been substantial growth in unmanned platforms of all sizes and shapes with a corresponding increase in payload numbers and capability. Many of these systems have been rapidly acquired and immediately fielded for warfighter use through the Joint Urgent Operational Needs (JUON) process. JUONs have successfully added significant capability to joint warfighting. While those unmanned systems were rapidly developed to meet the immediate needs of the warfighter in the short term, they have not undergone rigorous requirements review and joint coordination through the normal JCIDS process, to include systems interdependencies and interoperability. Further, their long term affordability, sustainability, and potential to contribute to long term enterprise-wide capability portfolios have not been fully considered. Consequently, they have not received due consideration in the context of broader joint capability areas (JCA) which provide structure and organization to Requirements Development.

DoD is moving toward revision of the JCIDS process which will streamline urgent and deliberate Capability Development to enable requisite timeliness in meeting warfighter needs, while giving important consideration to long term affordability and sustainability. JCIDS is a key supporting process for DoD acquisition and Planning, Programming, Budgeting, and Execution (PPBE) processes. It ensures the capabilities required by the warfighter are identified with their associated operational performance criteria in order to successfully execute the missions assigned. This process allows better understanding of the warfighting needs early in capability development and provides a more comprehensive set of valid prioritized requirements. The Department's acquisition arm can then focus on choosing options to meet well defined requirement capability.

Given today's highly constrained fiscal environment, it is imperative that the Department look at many areas where efficiencies can be gained to create unmanned systems that are both effective and affordable. The DoD will look at capitalizing upon commonality, standardization, and joint acquisition strategies among others. Also, the Department demands these unmanned systems be affordable at the outset and not experience significant cost growth in their development and production evolution. Additionally, it must provide the PPBE process with affordability advice by assessing the development and production lifecycle cost at the outset.

Capability requirements, validated by the JCIDS process, inform prioritization activities in the competition for funding during the PPBE process. The objective of the PPBE process is to provide the best mix of forces, equipment, and support attainable within fiscal constraints according to DoD Directive 7045.14, *Planning, Programming, Budgeting System (PPBS)*. To meet this objective, the PPBE process aims to meet goals established by the President and the Secretary of Defense (SECDEF) in the Strategic Planning and Joint Planning Guidance. In the PPBE process, the Services match available resources (fiscal, manpower, material) against validated requirements to achieve the strategic plan. A key task is to develop a

balanced/affordable capabilities-based Service program objective memorandum (POM). The POM position for the capability to meet a given requirement is reviewed by OSD and the final position becomes the President's Budget.

The Joint Capability Areas (JCAs)² are currently the preferred method the Department of Defense uses for reviewing and managing capabilities. The JCA framework provides the structure around which capabilities and capability gaps can be aligned across the Department and across the various portfolios to correlate similar needs, leverage effective solutions, and synchronize related activities. Also, various frameworks, such as the Universal Joint Task List (UJTL), are readily available to aid in identifying and organizing the tasks, conditions and required capabilities.

3.2 Unmanned Systems Applied to Joint Capability Areas

Mapping current and projected unmanned systems against the JCAs provides a sense of the Product Line Portfolio of unmanned systems and how it currently, and could in the future, contribute to the missions of the Department. Each JCA represents a collection of related missions and tasks that are typically conducted to bring about the desired effects associated with that capability. Nine Tier One JCAs are defined, and assessments identified that unmanned systems have the potential to be key contributors for Battlespace Awareness, Force Application, Protection, Logistics, and Building Partnerships. Although assessments have not yet been completed for the Force Support and Net Centric capability areas, missions and tasks in those JCAs receive significant support from unmanned systems as well.

Current technology and future advancements can and will enable single platforms to perform a variety of missions across multiple capability areas. This represents an opportunity for the Department to achieve a greater return on investment. Furthermore, the projections show that there will be opportunities for joint systems to conduct missions for each of the Services, just as there will be situations in which domain conditions or Service missions will dictate unique solutions. Detailed descriptions of each of the systems identified for the capability areas, including specific tasks, performance attributes and integrated technologies can be found at the Unmanned Warfare Information Repository site: <https://extranet.acq.osd.mil/uwir/>. Below are the descriptions for the most relevant JCA.

3.2.1 Battlespace Awareness (BA)

Battlespace Awareness is a capability area in which unmanned systems in all domains have the ability to significantly contribute well into the future to conduct ISR and environment collection related tasks. To achieve this, unmanned systems development and fielding must include the Tasking, Production, Exploitation, and Dissemination (TPED) processes required to translate vast quantities of sensor data into a shared understanding of the environment. There are many ongoing efforts to streamline TPED processing. Applications in this JCA range from tasks such as aerial and urban reconnaissance, which is performed today by Predators, Reapers and Global Hawks in the air and by PackBots and Talons on the ground, to tasks such as Expeditionary Runway Evaluation, Nuclear Forensics, and Special Reconnaissance. In the future, technology will enable

² <http://www.dtic.mil/futurejointwarfare>

mission endurance to extend from hours to days to weeks so that unmanned systems can conduct long endurance persistent reconnaissance and surveillance in all domains. Because unmanned systems will progress further with respect to full autonomy, on-board sensors that provide the systems with their own organic perception will contribute to Battle Space Awareness regardless of their intended primary mission. This capability area is one that lends itself to tasks and missions being conducted collaboratively across domains, as well as teaming within a single domain.

3.2.2 Force Application (FA)

Force Application is another JCA which includes a proliferation of unmanned systems contributing to maneuver and engagement. Today, Predator, Reaper and Gray Eagle UAS are weaponized to conduct offensive operations, irregular warfare, and high value target / high value individual prosecution, and this trend will likely continue in all domains. In the air domain, projected mission areas for UAS include air-to-air combat and suppression and defeat of enemy air defense. On the ground, UGVs are projected to conduct missions such as non-lethal crowd control, dismounted offensive operations, and armed reconnaissance and assault operations. In the maritime domain, UUVs and USVs are projected to be particularly suited for mine laying and mine neutralization missions.

DoD personnel must comply with the law of war, including when using autonomous or unmanned weapon systems. For example, Paragraph 4.1 of DoD Directive 2311.01E, DoD Law of War Program, May 9, 2006, requires that: "[m]embers of the DoD Components comply with the law of war during all armed conflicts, however such conflicts are characterized, and in all other military operations." Current armed unmanned systems deploy lethal force only in a fully human-operated context (level 1) for engagement decisions. For these systems, the decisions both to employ force and to choose which specific target to engage are made by a human. The United States operates defensive systems for manned ships and installations that have human-supervised autonomous modes (level 3), and has operated these systems for decades. For the foreseeable future, decisions over the use of force and the choice of which individual targets to engage with lethal force will be retained under human control in unmanned systems.

3.2.3 Protection

Protection has particular unmanned systems applicability to assist in attack prevention or effects mitigation. Unmanned systems are ideally suited for many protection tasks that are deemed dull, dangerous or dirty. As the future enables greater automation with respect to both navigation and manipulation, unmanned systems will be able to perform tasks such as fire fighting, decontamination, forward operating base security, installation security, obstacle construction and breaching, vehicle and personnel search and inspection, mine clearance and neutralization, sophisticated explosive ordnance disposal, casualty extraction and evacuation, and maritime interdiction. In the Protection JCA teaming within domains and collaboration across domains will likely prevail.

3.2.4 Logistics

The Logistics joint capability area is also ideally suited for employing unmanned systems in all domains to deploy, distribute, and supply forces. Transportation of supplies is an applicable, routine task, particularly suited for unmanned systems in all types of ground terrain.

Maintenance related tasks such as inspection, decontamination, and refueling can be performed by unmanned systems. Munitions and material handling, and combat engineering are ideal tasks that can be allocated to unmanned systems to enhance safety as well as increase efficiency. Additionally, casualty evacuation and care, human remains evacuation, and urban rescue can also be tasks performed by unmanned systems. Unmanned systems will perform Logistics tasks on home station as well as forward deployed.

Table 2. DoD Unmanned Capabilities by Program below is a sample mapping of JCA tasks to the current unmanned inventory and is provided for determining current unmanned systems capabilities.

Table 2. DoD Unmanned Capabilities by Program

AIRCRAFT					
System	Lead Service	Primary JCA	Mission Capabilities	ACAT	Acquisition Status
GROUP 1					
RQ-16B T_Hawk	US Navy	N/A	ISR/RSTA, EOD	Non-ACAT	Other
Wasp	US Air Force	BA	ISR/RSTA	Non-ACAT	Other
RQ-11B Raven	US Army	BA	ISR/RSTA	IV(T)	Production
Puma AE	USSOCOM	N/A	ISR/RSTA, FP	III	Production/Sustainment
GROUP 2					
Scan Eagle	US Navy , US Marines	N/A	ISR/RSTA, Force Protection	Non-ACAT	Other
GROUP 3					
RQ-7B Shadow	US Army, US Marines	BA	ISR/RSTA, C3, Force Protection	II	Production
S 100	USSOCOM	N/A	ISR/RSTA, EW, Force Protection	III	Design &Development
STUAS RQ-21A	US Navy , US Marines	BA	ISR/RSTA, EOD, Force Protection	III	Design &Development
Viking 400	USSOCOM	N/A	ISR/RSTA, EW, Force Protection	III	Design &Development
GROUP 4					
MQ-5B Hunter	US Army	N/A	ISR/RSTA, C3, Log, PS/TCS, FP	N/A	Other
MQ-1C Gray Eagle	US Army	BA	ISR/RSTA, C3, Log, PS/TCS, FP	I D	Production
MQ-1B Predator	US Air Force	BA	ISR/RSTA, PS/TCS, FP	I D	Sustainment
MQ-8B VTUAV	US Navy		ISR/RSTA, ASW, SUW/ASUW,	I C	MS-C
GROUP 5					
MQ-4 BAMS	US Navy		ISR/RSTA, EW, PS/TCS, SUW/ASUW, FP	I D	Design &Development
MQ-9A Reaper	US Air Force	FA	ISR/RSTA, EW, PS/TCS, FP	I D	Production
RQ-4A Global Hawk	US Air Force	BA	ISR/RSTA, C3, PS/TCS	I D	Sustainment
RQ-4B Global Hawk	US Air Force	BA	ISR/RSTA, C3, PS/TCS	I D	Production/Sustainment
MR UAS	US Navy	N/A	TBD	N/A	Concept
UCLASS	US Navy	N/A	TBD	N/A	Concept
MQ-X	US Air Force	FA	ISR/RSTA, PS/TCS, FP	N/A	Concept
Group 4	US Marines	N/A	TBD	N/A	Concept

Table 2. DoD Unmanned Capabilities by Program (continued)

GROUND VEHICLES					
System	Lead Service	Primary JCA	Mission Capabilities	ACAT	Acquisition Status
WHEEL					
MARCBot IV N	US Army	N/A	ISR/RSTA, IED Inv.	Other	Other
Throwbot	US Army	N/A	ISR/RSTA	Other	Other
Mine Area Clearance Equipment (MACE)	US Air Force	N/A	Mine, EOD, FP	Other	Concept
Defender	US Air Force	N/A	FA, FP, Fire	Other	Concept
TRACK					
ISR UGV	US Navy	N/A	ISR/RSTA, Fire Support, EOD	Other	Other
xBot	US Army	N/A	ISR/RSTA, EOD, IED Inv.	Other	Other
PackBot FIDO	US Army	N/A	ISR/RSTA, EOD, IED Inv.	Other	Other
M 160	US Army	N/A	Mine Neutralization	III	Design & Development
RC50 60	US Army	N/A	EOD, Mine Neutralization	Other	Other
Mini EOD	US Army	N/A	EOD	Other	Other
ANDROS HD 1	US Army	N/A	EOD	Other	Other
PackBot EOD	US Army	N/A	EOD	Other	Other
TALON IIIB	US Army	N/A	EOD, route clearance	Other	Other
TALON IV	US Army	N/A	EOD, route clearance	Other	Other
Panther II	US Army	N/A	EOD, Mine Neutralization	Other	Other
MK 1 MOD 0 Robot EOD	US Navy	N/A	EOD	IV	Sustainment
MK 2 MOD 0 Robot EOD	US Navy	N/A	EOD	IV	Sustainment
MK 2 MOD 0 RONS	US Navy	N/A	EOD	IV	Sustainment
All-Purpose Remote Transport System (ARTS)	US Air Force	N/A	Mine, EOD, FP, Fire	Other	Other
F6A ANDROS	US Air Force	N/A	EOD	Other	Other
HD 1	US Air Force	N/A	EOD	Other	Other
IVAN	US Air Force	N/A	EOD, FP	Other	Concept

Table 2. DoD Unmanned Capabilities by Program (continued).

MARITIME CRAFT					
System	Lead Service	Primary JCA	Mission Capabilities	ACAT	Acquisition Status
SURFACE					
Autonomous Unmanned Surface Vehicle (AUSV)	US Navy	N/A	ISR/RSTA	Other	Other
Mine Countermeasures (MCM) Unmanned Surface Vehicle USV	US Navy	BA	MIW/OMCM	Other	Concept
Anti-Submarine Warfare (ASW) Unmanned Surface Vehicle (USV)	US Navy	N/A	ASW	Other	Other
Sea Fox	US Navy	N/A	ISR/RSTA, FP	Other	Other
Remote Minehunting System (RMS), AN/WLD-1(V)1	US Navy	BA	MIW/OMCM	I D	Design & Development
Modular Unmanned Surface Craft Littoral	US Navy	N/A	ISR/RSTA	Other	Other
UNDERWATER					
Sea Stalker	US Navy	N/A	ISR/RSTA	Other	Other
Sea Maverick	US Navy	N/A	ISR/RSTA	Other	Other
Echo Ranger	Commercial	N/A	Insp/ID, Oceanographic Survey	Other	Other
Marlin	Commercial	N/A	Insp/ID, Oceanographic Survey	Other	Other
Surface Countermeasure Unmanned Undersea Vehicle	US Navy	BA	MIW/OMCM	III	Concept
MK18 Mod 2 Kingfish UUV System	US Navy	Protection	SUW/ASUW, MIW/OMCM, Insp/ID	PIP	Production
Surface Mine Countermeasure Unmanned Undersea Vehicle User Operational Evaluation System Increment 2	US Navy	N/A	MIW/OMCM	Other	Other
Surface Mine Countermeasure Unmanned Undersea Vehicle User Operational Evaluation System Increment 1	US Navy	N/A	MIW/OMCM	Other	Other
Battlespace Preparation Autonomous Underwater Vehicle (BPAUV)	US Navy	N/A	MIW/OMCM	Other	Other
HULS	US Navy	Protection	MIW/OMCM, EOD, Insp/ID	Abbr Acq	Production
MK18 Mod 1 Swordfish UUV System	US Navy	Protection	MIW/OMCM, EOD, Insp/ID	Abbr Acq	Sustainment
Large Displacement Unmanned Underwater Vehicle (LDUUV)	US Navy		ASW, ISR, MCM	Other	Concept
MK18 Mod 1 Swordfish UUV System	US Navy		MIW/OMCM, EOD, Insp/ID	Abbr Acq	Sustainment

3.3 Unmanned Aircraft Systems (UAS)

The air domain has received the greatest concentration of visibility as DoD has embraced unmanned technologies. Table 1 depicts that UAS investments will continue to consume a large share of the overall DoD investment in unmanned systems. These efforts have fielded a large number of UAS capable of executing a wide range of missions. Originally, UAS missions focused primarily on tactical reconnaissance; however, this scope has been expanded to include most of the capabilities within the ISR and battlespace awareness mission areas. UAS are also playing a greater role in strike missions as the military departments field multiple strike mission-capable weapon systems for time-critical targeting. Figure 1 below illustrates the variety of platforms in today's force structure.

DoD Unmanned Aircraft Systems (As of 1 JULY 2011)					
General Groupings	Depiction	Name	(Vehicles/GCS)	Capability/Mission	Command Level
Group 5 • > 1320 lbs • > FL180		•USAF/USN RQ-4A Global Hawk/BAMS-D Block 10 •USAF RQ-4B Global Hawk Block 20/30 •USAF RQ-4B Global Hawk Block 40	•9/3 •20/6 •5/2	•ISR/MDA (USN) •ISR •ISR/BMC	•JFACC/AOC-Theater •JFACC/AOC-Theater •JFACC/AOC-Theater
		•USAF MQ-9 Reaper	•73/85* *MQ-1/MQ-9 some GCS	•ISR/RSTA/EW/ STRIKE/FP	•JFACC/AOC- Support Corps, Div, Brig, SOf
Group 4 • > 1320 lbs • < FL180		•USAF MQ-1B Predator	•165/85*	•ISR/RSTA/STRIKE/FP	•JFACC/AOC-Support Corps, Div, Brig
		•USA MQ-1 Warrior/MQ-1C Gray Eagle	•31/11	•(MQ-1C Only-C3/LG)	•NA
		•USN UCAS- CVN Demo •USN MQ-8B Fire Scout VTUAV	•2/0 •14/8	•Demonstration Only •ISR/RSTA/ASW/ ASUW/MIW/OMCM/ EOD/FP	•NA •Fleet/Ship
Group 3 • < 1320 lbs • < FL180 • < 250 knots		•SOCOM/DARPA/USA/USMC A160T Hummingbird	•8/3	•Demonstration Only	•NA
		•USA MQ-5 Hunter	•45/21	•ISR/RSTA/BDA	•Corps, Div, Brig
		•USA/USMC/SOCOM RQ-7 Shadow	•368/265	•ISR/RSTA/BDA	•Brigade Combat Team
Group 2 • 21-55 lbs • < 3500 AGL • < 250 knots		•USN/SOCOM/USMC RQ-21A ScanEagle	•122/13	•ISR/RSTA/FORCE PROT	•Small Unit/Ship
		•USA / USN / USMC / SOCOM RQ-11 Raven	•5628/3752	•ISR/RSTA	•Small Unit
Group 1 • 0-20 lbs • < 1200 AGL • < 100 knots		•USMC/ SOCOM Wasp	•540/270	•ISR/RSTA	•Small Unit
		•SOCOM SUAS AECV Puma	•372/124	•ISR/RSTA	•Small Unit
		•USA gMAV / USN T-Hawk	•270/135	•ISR/RSTA/EOD	•Small Unit

Figure 1. DoD UAS

As the number of fielded systems has expanded, flight hours have dramatically increased as depicted in Figure 2.

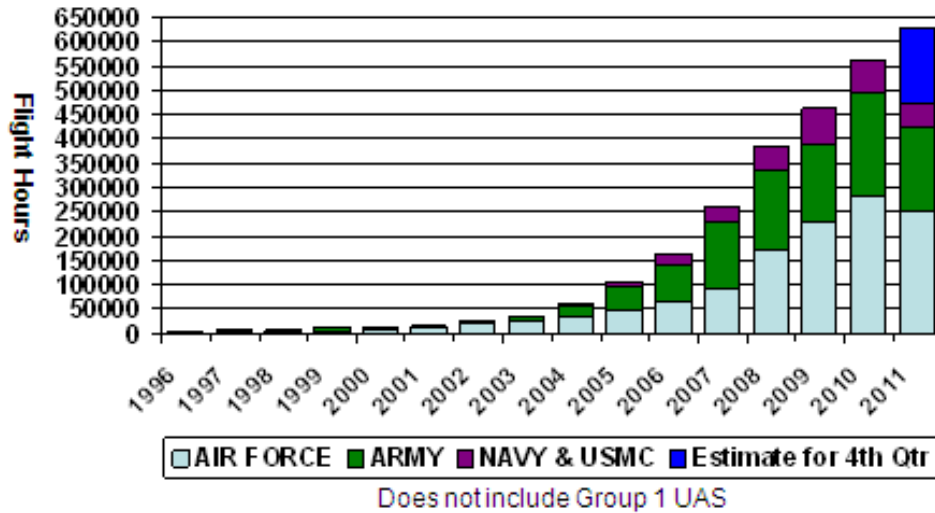


Figure 2. UAS Flight Hours (1996–Present)³

In 2009, DoD completed almost 500,000 UAS flight hours just in support of Operation Enduring Freedom and Operation Iraqi Freedom. In May 2010, unmanned systems surpassed one million flight hours and in November 2010 achieved one million combat hours. As these systems continue to demonstrate their value, this number will continue to grow.

... remotely piloted vehicles have flown more than 21,000 sorties so far this year, already surpassing the roughly 19,000 drone flights last year.

– “U.S. Uses Attacks to Nudge Taliban Toward a Deal,” *New York Times*, October 15, 2010.

3.4 Unmanned Ground Systems (UGS)

Since operations in Iraq and Afghanistan began, DoD has acquired and deployed thousands of UGS. These systems support a diverse range of operations including maneuver, maneuver support, and sustainment. Maneuver operations include closing with and neutralizing the enemy using speed and firepower. Maneuver support missions include mitigating natural and artificial obstacles and hazards. Sustainment missions leverage maintenance and support UGVs associated with combat services support.

Approximately 8,000 UGVs of various types have seen action in Operation Enduring Freedom and Operation Iraqi Freedom. As of September 2010, these deployed UGVs have been used in over 125,000 missions, including suspected object identification and route clearance, to locate and defuse improvised explosive devices (IEDs). During these counter-IED missions,

³ Updated 30 June 2011.

Army, Navy, and USMC explosive ordnance teams detected and defeated over 11,000 IEDs using UGVs, such as the one depicted in Figure 3.



Figure 3. Talon Ordnance Disposal Robot Preparing to Unearth Simulated IED

The lessons collected on the battlefield must be translated into programs that can be sustained. The rapid fielding and proliferation of unmanned systems and the subsequent battlefield modernization they provided have met the mission, but resulted in configuration and maintenance challenges. These ground systems continue to provide tremendous benefit to the ground commander, but improvements in user interfaces, reliability, survivability, and advances in 360° sensing, recording fidelity, and CBRN and explosive detection are required to meet the challenges anticipated in future conflicts. Figure 4 shows the UGS Family of Systems (FoS).

On Gordon's (UGV) final days, he was launched out of the truck and was searching an intersection for a possible deep buried IED. As he was on his way to the intersection, the IED was detonated about 10 ft from his location. Still functioning, he continued to search the area. On the opposite side of the road, another IED was detonated and had turned him upside down. Everything was still working until a fire fight started.

Gordon took 7 rounds to the underside and was done for the day. I took him to the robot shop for repair. It took 3 days. When he was returned to us, I put him back in the truck to get him back on duty. But this was shortly lived as he was searching a gate at a house for possible booby-traps that detonated directly next to him. Gordon was mangled beyond repair. Now his replacement "Flash" is here to finish his job.

-- Insight from an End User: *"Gordon" TALON Defeats IEDs and Saves Lives in Baghdad*, submitted by an EOD operator, summer 2007, Iraq.

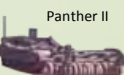
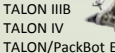
Unmanned Ground Systems				
Mission Areas	Air Force	Army	Navy	Other
Maneuver <u>Neutralize the enemy:</u> • IED Defeat Systems • Disarm / Disrupt • Reconnaissance • Investigation • Explosive Sniffer	All-Purpose Remote Transport Sys (ARTS)  F6A-ANDROS / HD-1 	MARCbot IV-N  Throwbot  xBOT / PackBot FIDO 	Mk1 Mod 0 Robot EOD Mk2 Mod 0, Robot EOD Mk3, Mod 0, Remote Ordinance Neutralization System (RONS)   Advanced EOD Robotic System (AEODRS)	
Maneuver Support <u>Mitigate obstacles and hazards:</u> • Area/Route Clearance • Mine Neutralization • Counter IED • CBRNE	Defender  Mine Area Clearance Equipment (MACE) 	MV-4B  Panther II 	ISR UGV (Chaos Gold) 	Local Area Network Droids (LANDroids) 
Sustainment <u>Maintain and support:</u> • Common Robotic Kit • EOD • Convoy • Log/Resupply	Immediate Visualization & Neutralization (IVAN) 	RC50/60  Mini-EOD  R-Gator  Andros HD-1  TALON IIIB  TALON IV  TALON/PackBot EOD 	SOF Beach Reconnaissance UGV 	DARPA - Legged Squad Support System  SOCOM - Autonomous Expeditionary Support Platform (AESP)

Figure 4. UGS FoS

3.5 Unmanned Maritime Systems (UMS)

Over 90% of the information, people, goods, and services that sustain and create opportunities for regional economic prosperity flow across the maritime domain. With emerging threats such as piracy, natural resource disputes, drug trafficking, and weapons proliferation, a rapid response capability is needed in all maritime regions. DoD continues to expand the range of missions supported by unmanned systems in the maritime domain. A recent study concluded

USVs, along with UUVs, will have an important role in the conduct of MCM [mine countermeasures] as they are particularly well suited for the ‘dirty - dull - dangerous’ tasks that MCM entails. They provide persistence, which permits significant mine hunting and sweeping coverage at lower cost by multiplying the effectiveness of supporting or dedicated platforms. Additionally, they provide the potential for supporting an MCM capability on platforms not traditionally assigned a mine warfare mission.

– USV mission descriptions, *The Navy Unmanned Surface Vehicle Master Plan*, 23 July 2007

that unmanned maritime systems “have the potential to provide critical enabling capabilities for current NATO [North Atlantic Treaty Organization] maritime missions that can improve Alliance security and stability”.⁴

Like UAS and UGS, UMS have the potential to save lives, reduce human risk, provide persistent surveillance, and reduce operating costs. UMS priority missions are listed below.

UMS can be defined as unmanned vehicles that displace water at rest and can be categorized into two subcategories: unmanned underwater vehicles (UUV) and unmanned surface vehicles (USV). USVs are UMS that operate with near-continuous contact with the surface of the water, including conventional hull crafts, hydrofoils, and semi-submersibles.⁵ UUVs are made to operate without necessary contact with the surface (but may need to be near surface for communications purposes) and some can operate covertly.



The use of UMS is not new. After World War II, USVs were used to conduct minesweeping missions and test the radioactivity of water after each atomic bomb test. Another example occurred during the Vietnam War in an area south of Saigon, where remotely controlled USVs conducted minesweeping operations. More recently, UUVs conducted mine-clearing activities during Operation Iraqi Freedom in 2003. A complementary suite of UMS serve as the foundation for MCM operations from the Littoral Combat Ship (LCS) and small diameter UUVs are currently the main mine detection capability for ports & harbor and in the Very Shallow Water zone.

At a recent Science and Technology Conference hosted by the Office of Naval Research, Chief of Naval Operations (CNO) Admiral Gary Roughead made a number of statements expressing UMS goals for the Department of the Navy. Solving the power consumption problem would be the “one thing” CNO would most like to see the Navy’s scientists accomplish.⁶ Rear Admiral Nevin Carr, Chief of Naval Research, explained the current efforts in filling the needs in this unmanned maritime area and went on to describe where and how this technology might be applied in the future: “Two options are under exploration: fuel-cell technologies and radioscope thermoelectric generators that can provide low amounts of power for very long periods of time. We might start thinking about setting up drone refueling stations. You might deploy a remotely manned underwater generator that sits on the bottom in a secure area, which is a secure location where your forward-deployed vehicles might come back and recharge.”

Figure 5 illustrates the variety of platforms and maritime missions supporting today’s operations by UMS and those planned for operation in the near future. They have the potential

⁴ The Combined Joint Operations from the Sea Centre of Excellence (CJOS/COE) Study (2009) for Maritime Unmanned Systems (MUS) in NATO, 8 December 2009.

⁵ Consistent with Navy USV Master Plan, 2007.

⁶ Ackerman, Spencer, Navy Chief Presses Nerds to Power Up Undersea Drones, Danger Room, Wired.com, 8 November 2010.

for even greater integration, especially UUVs, to the point of assisting the current submarine and surface fleet in replacing fixed underwater sensor grids; using UUVs and distributed netted sensors to expand our submarine's sphere of influence; and weaponizing UUVs.

However, there are currently limitations to realizing the full potential of UMS:

- Endurance
- Underwater C2 and deconfliction
- Survivability in an unforgiving environment
- Launch and recovery
- Communication technology for dynamic tasking, querying, and data dissemination

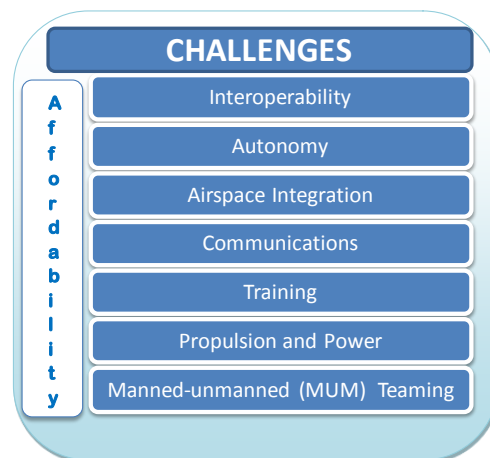
These challenges are areas for further technical exploration. Despite these challenges, the future for UMS is very promising. Building on the experience and contribution from this first generation of fielded UMS, the shift is underway from UMS merely serving as an extension of the sensor systems of manned ships and submarines into an integrated FoS to provide full mission capabilities with increased autonomy.

Unmanned Maritime Systems		
Mission Areas	Unmanned Surface Vehicles (USV)	Unmanned Underwater Vehicles (UUV)
Mine Counter-Measures (MCM)	Mine Countermeasure (MCM) USV  Remote Mine-hunting System (RMS) AN/WLD-1 	Surface Mine Countermeasure (SMCM) User Operational Evaluation -System Increment 1 -System Increment 2  Battlespace Prep Autonomous Undersea Vehicle (BPAUV)  Surface Mine Countermeasure (SMCM) UUV 
Anti-Submarine Warfare (ASW)	ASW USV 	
Maritime Security	SeaFox  Modular Unmanned Scouting Craft Littoral (MUSCL) Use Operational Evaluation 	Sea Stalker  Sea Maverick  Semi-Autonomous Hydrographic Recon Vehicle  Mk18 Mod1 Swordfish UUV Sys Mk18 Mod2 Kingfish UUV Sys Hull Underwater Vehicle / Hull Underwater Localization Sys (HULS)  Littoral Battlespace Sensing AUV  Littoral Battlespace Sensing Glider  ECHO Ranger 

Figure 5. DoD UMS FoS

3.6 Challenges for Unmanned Systems

The number of fielded systems and the range of missions supported by unmanned systems continue to grow at a dramatic rate. As DoD steers a path toward the vision described in Section 2, the challenges listed on the right must be overcome in order to realize the full potential offered by unmanned systems. The following subsections summarize these challenges and the remainder of this document provides details and future goals for dealing with each challenge.



3.6.1 Interoperability

To maximize the potential of unmanned systems, the systems must be capable of operating seamlessly with each other and with manned systems across the air, ground, and maritime domains. System interoperability is critical in achieving these objectives and requires the implementation of mandated standards and Interoperability Integrated Product Team (I-IPT) profiles. Properly implemented, interoperability can serve as a force multiplier, improve joint warfighting capabilities, decrease integration timelines, simplify logistics, and reduce total ownership costs (TOC). One of the most powerful tools in maximizing interoperability and achieving these objectives is the adoption of the open systems architecture concept.

3.6.2 Autonomy

The rapid proliferation of unmanned systems and the simultaneous operation of manned and unmanned systems as unmanned systems expand into additional roles have created a manpower burden on the Services. With limited manpower resources to draw upon, the Services are seeking ways to improve the efficiency of operations. For instance, introducing a greater degree of system autonomy will better enable one operator to control more than one unmanned system, and has the potential to significantly reduce the manpower burden. Additional benefits are greatly reducing high bandwidth communication needs and decreasing decision cycle time. Similar efficiencies can be gained by automating the tasking, processing, exploitation, and distribution (TPED) of data collected by unmanned systems. Autonomy can help extend vehicle endurance by intelligently responding to the surrounding environmental conditions (e.g., exploit/avoid currents) and appropriately managing onboard sensors and processing (e.g., turn off sensors when not needed). Implementing a higher degree of autonomy faces the following challenges:

- Investment in science and technology (S&T) to enable more capable autonomous operations
- Development of policies and guidelines on what decisions can be safely and ethically delegated and under what conditions
- Development of new Verification and Validation (V&V) and T&E techniques to enable verifiable “trust” in autonomy

3.6.3 Airspace Integration (AI)

The rapid increase in fielded UAS has created a strong demand for access within the NAS and international airspace. The demand for airspace to test new systems and train UAS operators has quickly exceeded the current airspace available for military operations. Figure 6 shows the projected number of DoD UAS locations in the next six years, many without access to airspace compatible for military operations under the current regulatory environment.

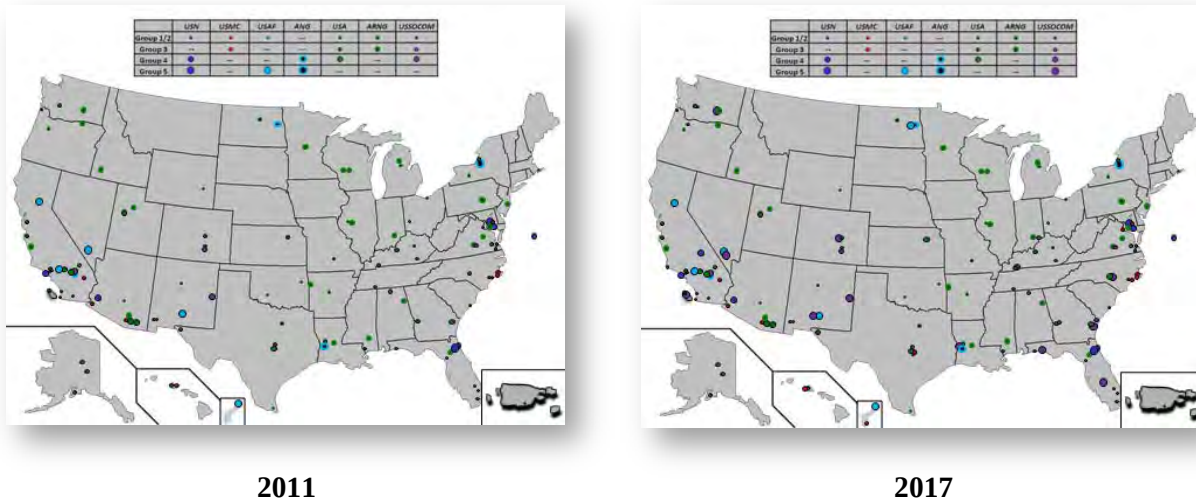


Figure 6. Representative DoD UAS Locations from 2011 to 2017.

NAS access for UAS is currently limited primarily due to regulatory compliance issues and interim policies. DoD UAS operations conducted outside of restricted, warning, and prohibited areas are authorized only under a (temporary) Certificate of Waiver or Authorization (COA) from the FAA. The COA process is adequate for enabling a small number of flights, but does not provide the level of airspace access necessary to accomplish the wide range of DoD UAS missions at current and projected operational tempos (OPTEMPOs). This constraint will only be exacerbated as combat operations in Southwest Asia wind down and systems are returned to U.S. locations.

3.6.4 Communications

Current unmanned systems operations involve a high degree of human interaction with the systems via various means for C2 and transmission of operational data. Protection of these communication links and the information flowing through them is critical to these operations. As the number of fielded systems grows, communications planners face challenges such as communication link security, radio frequency spectrum availability, deconfliction of frequencies and bandwidth, network infrastructure, and link ranges. Intelligent means of data parsing is needed to enable TPED and counter communication challenges.

3.6.5 Training

The rapid proliferation of numbers and types of UAS in response to wartime demand coupled with an expected redeployment of forces back to a peacetime footing will result in continuation training greater than what has been required in the past. This has caused pause to examine UAS training and to develop an overall strategy. At present, due to high demand for UAS assets in real world contingencies, most day-to-day, continuation training is accomplished under in-theater combat conditions. At the same time, disparate efforts by a number of organizations across the Department are underway to try to address UAS training requirements. As UAS forces drawdown in theater and redeploy, the Services will require comprehensive continuation and Joint force training in the peacetime environment at UAS bed-down and selected Joint training locations.

3.6.6 Propulsion and Power

The dramatic increase in the development and deployment of unmanned systems across the entire spectrum of air, ground, and maritime missions has led to a concurrent increase in the demand for efficient, powerful, often portable, and logistically supportable solutions for unmanned system propulsion and power plant requirements. As these systems continue to demonstrate their value, operators want them to function longer without refueling and to do more tasks; these demands tax the internal power sources. The laboratories of the military Services and industry are focusing their efforts to find efficient solutions to the demand for improved propulsion and power plants. Regardless of energy source, total vehicle design, from materials used to autonomous response to the physical environment, needs to be considered up front to maximize endurance.

3.6.7 Manned-Unmanned (MUM) Teaming

MUM teaming refers to the relationship established between manned and unmanned systems executing a common mission as an integrated team. U.S. military forces have demonstrated early progress in integrating unmanned systems within the existing manned force structure, but much more needs to be done to achieve the full potential offered by unmanned technology. Improving MUM teaming is both a technology challenge (such as connecting the systems) and a policy challenge (such as establishing the rules of engagement for operating semi-autonomous unmanned with manned systems).

4 INTEROPERABILITY

4.1 Overview

There is a clear benefit for warfighters to be able to seamlessly command, control, communicate with, exploit and share sensor information from unmanned systems across multiple domains. The Unmanned Systems Interoperability Initiative (UI2) led by the OSD UAS Task Force is in the process of developing an overarching strategy for increasing unmanned systems interoperability, with the long-range vision of producing a strategy that can be leveraged across the full spectrum of both unmanned and manned systems. DoD's goal is to move from Service/Agency-unique, stand-alone capabilities toward substantially improved interoperability standards that lead to an improved collaborative operational environment.

Lack of UAV interoperability has had a real-life impact on U.S. operations ... there have been cases where a Service's UAV, if it could have gotten data to another Service, another component, it may have provided better situational awareness on a specific threat in a specific area that might have resulted in different measures being taken.

– Dyke Weatherington (PSA/UW)

4.2 Functional Description

Interoperability is the ability to operate in synergy in the execution of assigned tasks.⁷ Properly implemented, it can serve as a force multiplier, improve warfighter capabilities, decrease integration timelines, simplify logistics, and reduce TOC. DoD Directive (DODD) 5000.1 establishes the requirement to acquire systems and FoSs that are interoperable.⁸ DoD's unmanned systems will need to demonstrate interoperability in a number of areas:

- *Among similar components of the same or different systems.* The plug-and-play use of different sensors on an unmanned vehicle.
- *Among different systems of the same modality.* An open common ground control station (GCS) architecture for multiple, heterogeneous unmanned vehicles.
- *Among systems of different modalities.* The ability of air, ground, and maritime vehicles to work cooperatively.
- *Among systems operated by different Military Departments under various CONOPS and TTP, i.e., in joint operations.* Joint service systems working in concert to execute a common task or mission.

⁷ Definition found in Joint Publication (JP) 1-02, Department of Defense Dictionary of Military and Associated Terms, 12 April 2001 (as amended through 17 March 2009).

⁸ DODD 5000.1, Enclosure 1, paragraph E1.10.

- *Among systems operated and employed by coalition and allied militaries under the governance of various concepts of employment (CONEMPs), TTPs, e.g., in multinational combined operations or NATO STANAGs.* The ability of coalition and allied systems to work in concert to execute a common task or mission based on predefined roles and responsibilities.
- *Among military systems and systems operated by other entities in a common environment.* The ability of military UAS to share the NAS and international airspace with commercial airliners and general aviation.
- *Among systems operated by non-DoD organizations, Allies, and coalition partners, i.e., in combined operations.* The ability of assets from organizations such as Customs and Border Protection (CBP) and Department of Homeland Security (DHS) to coordinate, interoperate, and exchange information with DoD assets of the same modality and same model.

The interoperability goal for Unmanned Systems is an ability to provide data, information, material, and services to and accept the same from other systems, units, or forces ... and to use the exchanged data, information, material, and services to enable them to operate effectively together.

The Joint Unmanned Aircraft Systems Center of Excellence (JUAS COE)⁹ maintains the Joint CONOPS for UAS, which provides a joint vision for the operation, integration, and interoperability of UAS and touches on several of the areas mentioned above. Figure 7 illustrates joint, cross-domain interoperability.

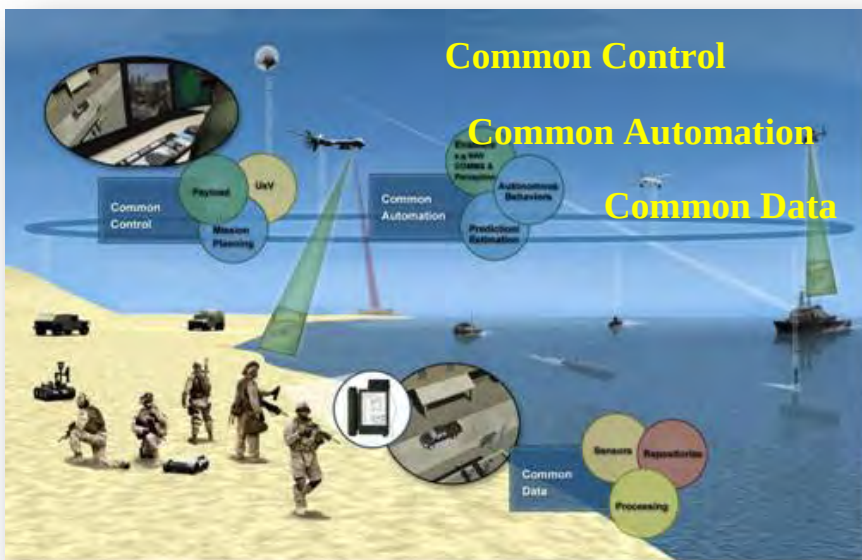


Figure 7. Joint Cross-Domain Interoperability.

⁹ JCOE is being disbanded June 2011 and its tasks are being transferred to the Joint Staff.

4.3 Today's State

The historical approach to software and hardware acquisition relied on dedicated design for each system to accomplish a specific mission or capability. This approach may be optimal for a single system, but it unfortunately produces a collection of discrete, disjointed solutions with significant functional overlap and no method to exploit common components of each system.

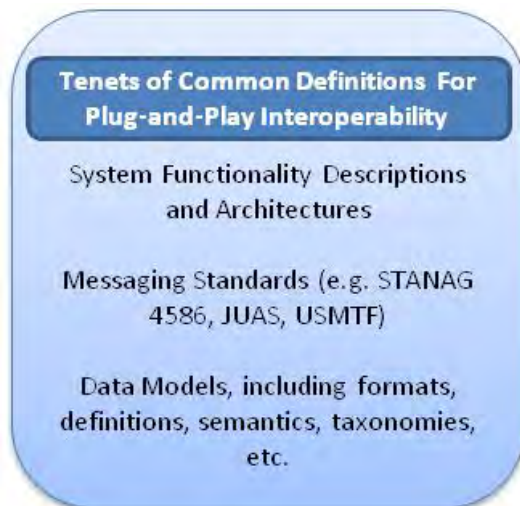
Open architecture (OA) facilitates interoperability between systems by effectively leveraging the following concepts:

- Common capability descriptions in system requirements
- Common, open data models, standards, interfaces, and architectures in system design
- Common components in system acquisition strategies

OSD defines OA as a multifaceted strategy providing a framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures. This framework includes a set of principles, processes, and best practices that:

- Provide more opportunities for competition and innovation
- Rapidly field affordable, interoperable systems
- Minimize total ownership cost
- Optimize total system performance
- Yield systems that are easily developed and upgradeable
- Achieve component software reuse¹⁰

These (predominantly) acquisition issues are aided by a solid framework for software, component, and systems interoperability.



Traditionally, efforts have focused on system functionality descriptions, with interoperability focused at the messaging layer (e.g., the Joint Architecture for Unmanned Systems (JAUS) and STANAG 4586) to achieve standards-based interoperability. However, the tenets of common definitions and understanding listed on the left are required to achieve a true plug-and-play level of interoperability in which software capabilities from multiple vendors can be developed and integrated into a single system, supporting the exchange, interpretation, and action on data from other systems.

Through implementation and program-level

¹⁰ Terms and Definitions, Defense Acquisition University, <https://acc.dau.mil/CommunityBrowser.aspx?id=22108>.

adoption of these three tenets, DoD intends to address the issue of single proprietary vendor dependency within the acquisition system and improve conditions allowing for full competition.

4.4 Problem Statement

Over the last decade, the DoD has achieved great successes from the use of unmanned systems for both peacetime and wartime operations. These successes led to a significant increase in the number of unmanned systems planned and procured, and the future looks to see an exponential increase in the quantity and diversity of unmanned systems applications. Traditionally, each unmanned system was procured as a vertically integrated, vendor-

proprietary solution, consisting of the vehicle system, control station, communications channels, and encryption technologies. These single-system variants were typically “closed” systems utilizing proprietary interfaces. Development of the entire system was conducted in parallel with close interdependencies between components and procured as a whole through the platform prime contractor. As the number of new unmanned systems programmed in the Service budgets increased, the magnitude of RDT&E requirements for development skyrocketed. In addition to cost, this approach resulted in a number of unfavorable acquisition and growth characteristics that impeded progress as depicted above. Further, silence about the lack of interoperability and standards failed to foster dialog on how to overcome them. Over time, this resulted in an inhibition to innovation; increased vulnerability to threats where attacks on common attributes can impact multiple systems; increased complexity to systems engineering, development, and test; increased upfront costs; increased costs to system upgrades that cannot be made without changes to the interoperable dependencies of multiple systems; and budgeting protocols that treat interservice and coalition interoperability as fiscal trade-space.

These issues have significantly hampered unmanned systems acquisition activities. However, urgent wartime needs dictated that such concerns be relegated to the background, in the interest of rapid initial deployment. As the unmanned systems industry matures, however, the acquisition process must evolve in parallel. Addressing and enabling interoperability within unmanned systems will help accomplish this goal.

Unfavorable Characteristics of Current Approach

- Lack of re-usability, resulting in RDT&E dollars being inefficiently utilized on repeated development of similar technology for different platforms.
- Difficulty of upgrading and enhancing capability due to the proprietary nature of UxVs.
- Inability to leverage research and development conducted at small businesses.
- Reliance on large prime vendors and vertical integrators who have little motivation for controlling and managing schedule.

4.5 The Way Ahead

The technical approach to achieve the interoperability vision leverages the tight connection between interoperability and OAs, and consists of several elements. Each of the following elements is required, and none is sufficient in its own right to implement an OA:

- Development of a standard data model and service definitions that support OA concepts.
- Development of multiple repositories of models, software components, interface standards, and infrastructure services that can be used across the Services to extend, adapt, and compose unmanned systems and support software component reuse. These repositories should encourage the use of commercial, off-the-shelf (COTS) solutions where available, and are not intended to be “single point bottlenecks” as other efforts have been in the past. The goal is to provide multiple collection points across the Services for best practices, interfaces, and implementations.
- Collaboration among Government, industry, and academia to extend and manage the repositories and to validate components.
- Migration of current and developing systems to the OA approach.

To meet current interoperability standards, DoD will rely more heavily on spiral and incremental development initiatives ensuring services are compliant with these standards.

4.5.1 Open Architecture (OA)

OA utilizes a common set of interfaces and services; associated data models; robust, standard data busses; and methods for sharing information to facilitate development. OA involves the use of COTS components with published, standard interfaces, where feasible, at all levels of system design. This approach avoids proprietary, stove-piped solutions that are vendor-specific and enables innovation to be better captured and integrated into systems design. The OA approach allows for expanded market opportunities, simplified testing and integration, and enhanced reusability throughout the program life cycle. The Navy’s Cruiser Modernization Program is one such effort.



The OA process encourages innovation, allows information sharing among competitors, and rewards Government and industry for this collaboration. It allows programs to include small businesses in systems acquisition activities as a valuable, affordable, and innovative source of technologies and capabilities. The result is a better product.

DoD unmanned systems consist of a wide range of programs, architectures, and acquisition approaches. To create a common framework for development and acquisition, DoD adopted principles of OA and service-oriented architecture (SOA). While the OA is the contracting, architecture, and business process methodology used to develop and acquire systems, a SOA is a specific way of designing software, in a standardized architecture, that uses interchangeable and interoperable software components called *services*. When coupled together, the result is a business approach to acquiring software developed within a common engineering construct that promotes reuse, cost reduction, competition, growth opportunity, expandability, innovation, and interoperability among similar systems.

SOA provides a set of principles or governing concepts that are used during the phases of systems development and integration. This type of architecture attempts to package functionality as interoperable services within the context of the various business domains that use it. SOAs increase functionality by incorporating new services, which are developed separately but integrated within the system's common framework as a new capability. Their interfaces are independent of application behavior and business logic, and this independence makes the interfaces agile in supporting application changes and enables operations across heterogeneous software and hardware environments.

Programs and efforts to date have strongly tied together unmanned systems capability requirements and definitions, along with underlying technology selections. In recognition of the rapidly changing technology, unmanned systems architectures would benefit strongly from being defined at a platform-independent model (PIM) level, which is devoid of technology dependence.

The PIM level allows for definition of domains, software components, interfaces, interaction patterns, and data elements without flattening them to a specific set of computing, communications, and middleware technologies. Aside from enabling technology-independent design, this approach, as formalized in model-driven engineering principles, fosters interoperability.

At a minimum, a common set of interfaces and messaging standards is required for interoperability. Without a common semantic understanding of what data represent, there is significant opportunity for lack of interoperability, even if messages are correctly parsed and interfaces are followed. Therefore, a key final aspect is the recognition that data modeling is a separate, core aspect for defining interoperable systems. This aspect includes specifying definitions, taxonomies, and other semantic information to ensure there is a common understanding about what information a specific data item imparts.

This approach supports the involvement of multiple organizations in the development of one or more services, and results in increased innovation, flexibility, and improved performance. SOAs, however, constitute only one approach to implementation of OAs. Certain programs may not need SOAs. The program manager will determine the correct architecture to implement. Regardless of whether SOA approach is used, DoD has mandated an OA approach in software development. The program manager will be responsible for implementing an environment that will support OA in both programmatic and technical areas.

4.5.2 Service Repositories

DoD recognizes that there is rarely a one-size-fits-all solution to the challenging problem of software and service reuse. However, service repositories fill a growing need within DoD for commonality, reuse, and reduced duplication of effort, all of which aid interoperability by leveraging common interfaces. Programs will have access to the service repositories for their use in planning and implementation. In addition, programs will be encouraged to contribute services (within Government Data Rights constraints) to the repositories for future reuse. Where programs have requirements that cannot be met by software within the repositories, existing

services may be extended to add functionality, and this approach should result in cost savings over the creation of brand new capabilities.

Constructing such repositories requires a commitment to OA, along with the adoption of existing and upcoming standards (e.g., SAE JAUS, STANAG 4586, UCS), so that a common framework exists with which to develop services. In addition, tools are necessary to ease adoption, reduce learning curves, and provide validation and certification capabilities. See Figure 8.

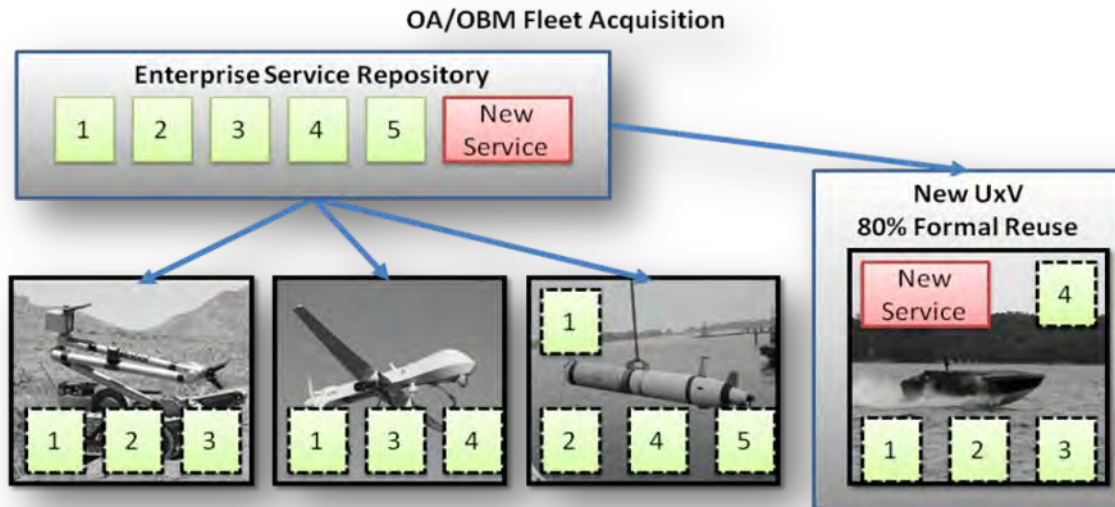


Figure 8. Cross-Domain Service Reuse Through an Enterprise Service Repository.

OA allows components to be developed once rather than redeveloped for each warfare area or mission. OA exploits software reuse and open interfaces to ensure unnecessary costs are not incurred in the redevelopment of core software. The OA approach described in this section utilizes collaboration among Government, industry, and academia to comply with principles of modularity, reusability, interoperability, affordability, and competition to develop reusable products.

Through implementation of the OA approach, DoD will develop and establish a domain service portfolio management (DSPM) repository for new acquisition and in-service programs. This repository will contain program-related software services information including standard architectures, design guidelines, service interfaces, and specifications for designing new systems or modifying existing systems. Programs will be required to consult with the DSPM repository for software reuse, where applicable. As programs design new and unique software and services, they are required to populate the DSPM repository with new information and make the service available for reuse, within Government Data Rights constraints.

4.5.3 Collaborating Communities

DoD has long recognized the value in fostering collaboration between Government, industry, and academia in open forums to address interoperability and common standards. To that end, a

number of integrated product teams, working groups, and other communities have formed, under the auspices and support of OUSD(AT&L), to address the interoperability challenge. These forums have enabled the Government to engage with industry at all levels, from grassroots to executive, and have enabled DoD personnel to aid in the systems and architecture design process, rather than simply being customers. These collaborating communities exist within a variety of national and international standards bodies, span the domains of unmanned systems (i.e., UAS, UGS, UMS), and address key cross-domain areas as well as domain-unique capabilities. DoD intends to continue to support this type of collaboration as it fosters the development of OAs. Current examples of these communities include the following:

- The OUSD(AT&L)-chartered UAS Task Force to coordinate critical DoD UAS issues and develop a path to enhance operations, enable interdependencies, facilitate interoperability, and streamline UAS acquisition. Within the UAS Task Force, the I-IPT has been chartered to promote UAS interoperability across the Services. The I-IPT establishes a central coordination forum for the Services' acquisition organizations and participating industry partners to share ideas that will allow the Department to build interoperability within the deployed UAS infrastructure, individual systems, and interfaces with appropriate manned weapons systems and C2 capabilities.
- Under the guidance of the Defense Science and Technology Advisory Group, the Autonomy Systems Community of Interest (CoI) closely examine the DoD's S&T investments in the enabling of autonomous systems. Specifically, this CoI identifies potential investments to advance and initiate critical enabling technology developments and strategically assesses the challenges, gaps, and opportunities to develop and advance autonomous systems.
- The National Geospatial-Intelligence Agency (NGA) is a member of the U.S. Intelligence Community and a Department of Defense (DoD) Combat Support Agency. NGA provides support to civilian and military leaders and contributes to the state of readiness of U.S. military forces by providing geospatial intelligence (GEOINT) imagery, imagery intelligence and geospatial data (e.g., mapping, charting and geodesy), and information to ensure the knowledge foundation for planning, decision and action. NGA also contributes to humanitarian efforts, such as tracking floods and disaster support, and to peacekeeping. NGA provides unmanned systems, topographical and terrestrial data, geodesy and geophysical data, imagery and precise position and target data for unmanned system mission planning and UAS flight operations. GEOINT support includes aeronautical and safety of navigation data, vertical obstruction, digital terrain elevation data and hydrographic data.
- NATO's Joint Capability Group on Unmanned Aerial Vehicles (JCGUAV) directs interoperability efforts in unmanned aviation. JCGUAV subsumed NATO's three Military Department UAS-related groups (PG-35, Air Group 7, and Task Group 2) in 2006. Its major accomplishments to date include STANAG 4586 for UAS message formats and data protocols, STANAG 4671 for UAV Airworthiness Standard, and STANAG 7085 for the CDL communication system, which has been mandated by OSD since 1991.
- NATO's Joint Capability Group Intelligence Surveillance and Reconnaissance (JCGISR) provides interoperability between NATO and Coalition ISR systems and includes

standards related to imagery formats and interfaces, data storage interfaces, motion imagery, electronic intelligence reporting, and imaging systems data links.

- Current UAS System Interoperability Profiles (USIPs), produced by the I-IPT, define the standard interface for payload products and the data link between a control station and air vehicle for line of sight (LOS) and beyond line of sight (BLOS) scenarios. Future USIPs will address other aspects of interoperability to include data encryption, additional data link technologies such as bandwidth efficient common data link (BE-CDL), and enhanced capabilities provided by future sensors.
- The Joint Architecture for Unmanned Systems (JAUS) began in 1995 as an effort by the Army's program office for UGVs in the Aviation and Missile Research, Development and Engineering Center (AMRDEC) at Redstone Arsenal to establish a common set of message formats and data protocols for UGVs. Deciding to convert JAUS to an international industry standard, the program office approached the Society of Automotives Engineers (SAE), a standards development organization (SDO) with robotics experience, which established the AS-4 Unmanned Systems Committee in August 2004. AS-4 has three subcommittees focused on requirements, capabilities, and interfaces and an experimental task group to test its recommended formats and protocols before formally implementing them. The migration to the SAE is complete, and the first set of SAE JAUS standards, focusing on the JAUS Service Interface Definition Language (JSIDL), core services, mobility services, manipulation services, and environmental sensing services, has been balloted and released. Although AS-4 is open to its members creating standards on other aspects of unmanned systems beyond message formats and data protocols for UGVs, much of this broader work is now being undertaken by other UAS-related SDOs. STANAG 4586 is unmanned aviation's counterpart to JAUS.
- The Navy's Program Executive Officer of Littoral and Mine Warfare (PEO(LMW)) formally adopted JAUS message formats and data protocols for use with its UUVs, USVs, and UGVs in 2005. Working through SAE AS-4, the Naval Undersea Warfare Center (NUWC) expanded JAUS to serve the UMS community. It found only 21% of UMS message formats to be directly compatible with the formats of JAUS, with the high percentage of new formats needed possibly due to the operation of UMS in three dimensions versus the two dimensions of UGVs, for which JAUS was developed. UUV variants of JAUS services are in active development and have been presented to the SAE AS-4 committees.
- Under direction from the OUSD(AT&L),¹¹ the UAS Task Force chartered the UAS Control Segment (UCS) Working Group, which is tasked to develop and demonstrate a common, open, and scalable UAS architecture supporting UAS Groups 2 to 5 (see Fig 1. DoD UAS for Groupings). The UCS Working Group comprises Government and industry representatives and operates using a technical society model where all participants are encouraged to contribute in any area of interest. This effort incorporates the best practices of current Army, Air Force, and Navy development efforts to include, but not limited to, the following:

¹¹ OUSD(AT&L) Acquisition Decision Memorandum, 11 February 2009.

- Definition of a common functional architecture, interface standards, and business rules
- Use of open-source and Government-owned software as appropriate
- Competitive acquisition options
- Refinement of message sets to support all operational requirements of the systems previously defined

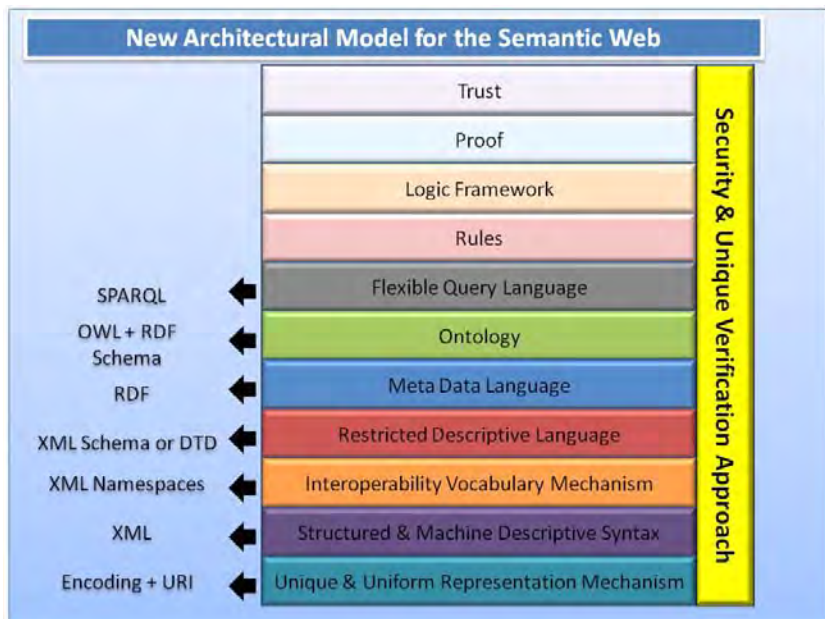
In addition to the definition of common capability descriptions, standards, data models, and architectures, DoD continues to promote the development of OA tools and to aid system acquisition and development in embracing the OA concepts. These efforts extend across the technology and unmanned vehicle spectrum, from software development kits, to complete architectures, addressing UGVs, UMVs, and UAVs, across all Services. Examples of such tools include:

1. The JAUS Tool Set (JTS) is a tool to help developers build JAUS-compliant software components without having to be intimately familiar with the details of JAUS. JTS allows an unmanned system designer to focus on behavior rather than messaging, protocol, and other considerations by providing a graphical user interface (GUI) service editor, validator, internal repository, C++ code generation, and hypertext markup language (HTML) document generation.

The Navy and OSD have supported and promoted the use of the JTS and have had success incorporating it into development and acquisition efforts. Use of JTS on programs accrues benefits to a number of stakeholders in the acquisition chain and RDT&E community.

These benefits include enabling a fair basis for competition among vendors so that true capabilities are evaluated; reducing vendor lock-in on unmanned systems; and enabling the development of a service repository for JAUS capabilities that have been developed and are available for reuse. JTS reduces the threshold for entry into developing JAUS-

compliant systems, opens the market to small businesses, and drives competition and innovation focused on core technology. In addition, JTS provides an accepted, common validation capability, which is critical to ensure systems maintain compliance with JAUS.



2. The STANAG 4586 Compliance Toolkit (4586CT) is an integrated set of software tools that provides passive, interactive, and automated test capability. Its core function is to verify the structure and content of data link interface (DLI) messages against both STANAG 4586 and “private” messages as defined to support service-, mission-, or platform-specific requirements. This nonintrusive capability is provided either in real time or during post-run analysis. Additionally, 4586CT can be interoperable with other DLI-compatible systems in either manual mode (where an engineer monitors and injects DLI messages into the network) or automated mode (in which 4586CT interacts directly with other DLI systems according to user-defined scripts and procedures).

These capabilities enable 4586CT to perform compliance testing at both the message level and the higher protocol session levels of unmanned systems relative to the STANAG 4586, and other more specific interoperability profiles. Complex DLI message dialogs can be monitored and system interaction sequencing verified as 4586CT follows user-defined test programs. Because 4586CT can function as a proxy for other unmanned system components, it is also used during system development and task-specific integration testing to provide insight into unmanned system interaction and performance. Multiple instances of 4586CT can also be utilized to perform rapid prototyping of interoperation protocols during profile design; as a result, 4586CT can be a useful tool during the development of interoperability standards themselves.

The T&E of interoperability continues to evolve with the growth of unmanned systems. The C2 of these systems presents unique test challenges as autonomous functionality expands to operating complex equipment over wireless links. The spectrum of test includes assessment of standards compliance, electromagnetic frequency testing, sensor standards, payload standards, systems interoperability, quantifiable task assessment, performance measurement, metrics development, congestion management, and performance baseline measures. The scope of operation includes operator, platform, communications grid, C2 teams, ground stations, sensor teams, and collaborating systems. While today’s test represents a migration of the test challenge represented by proprietary data exchange and data formats towards service-oriented architecture exchange, it is also conceivable that the cognitive nature of unmanned systems algorithm development may actually accelerate the need for semantic knowledge exchange T&E.

The rapid acquisition of quickly evolving unmanned systems will require an unmanned systems T&E capability that evolves at a pace that exceeds this evolution. The T&E of unmanned systems interoperability requires investment in information architectures, methodology, test scenario synthesis, model-based T&E, and cross-UAS usage case repositories.

4.5.4 System Migration

Services working with OUSD(AT&L) are exploring the business case for adopting an OA approach for current and in-development systems. While various challenges still remain in the adoption of OA, the goal in the next 12 months is to identify migration pathways for all current programs of record (see Figure 9).

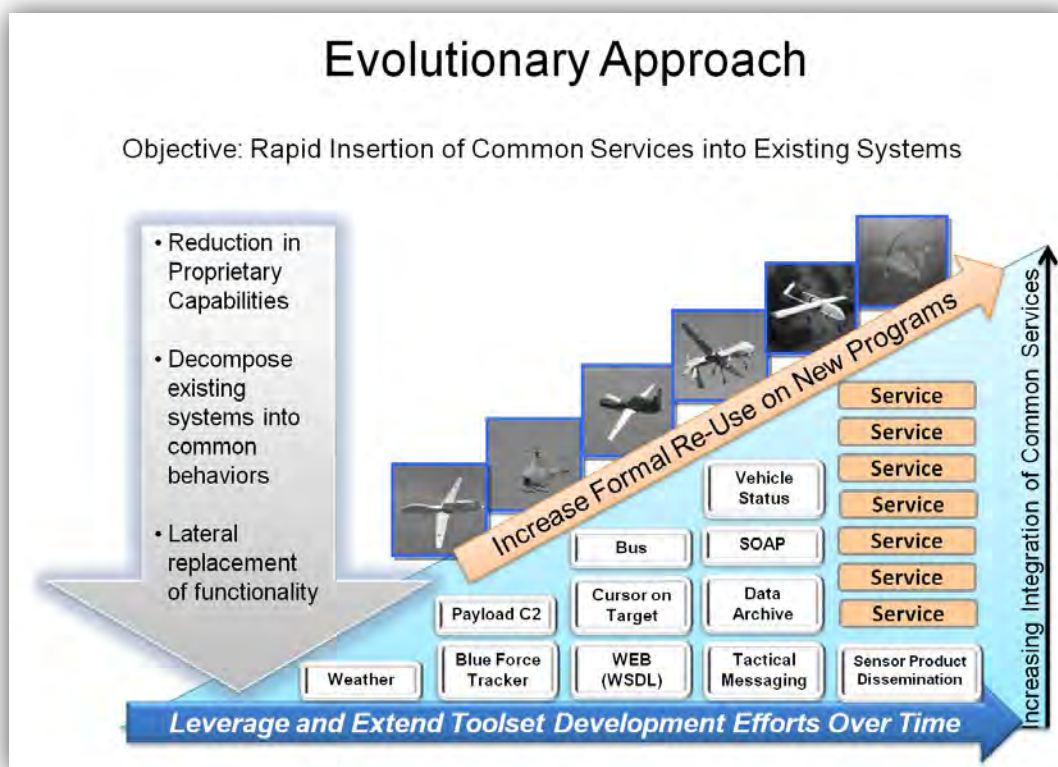


Figure 9. OA Migration Approach.

Quantifiable progress toward migration has already been achieved. The USAF Advanced Cockpit Block 50 (under development by General Atomics) has adopted UCS services and a common data bus. The July 2010 Block 50 implementation of takeoff, flight, payload C2, and landing utilized UCS-based software in a simulated flight environment demonstrated the architecture's utility. Additionally, Northrop Grumman has now agreed to tie its product lines into a common, open product line, with a joint mission-planning-mission-control system document signed by Northrop Grumman executives for synergy and collaboration between Broad Area Maritime Surveillance (BAMS) and Global Hawk unmanned systems. Advanced Explosive Ordnance Robotic System (AEODRS), utilizing an OA approach for hardware and software, is adopting SAE JAUS for messaging and is also developing interoperability profiles to ensure common system functionality descriptions, architectures, and data models. AEODRS is developing three classes of vehicles (dismounted operations, tactical operations, and base/infrastructure operations) with a common architecture and capability modules across the FoS. The AEODRS architecture defines the logical, mechanical, and electrical interfaces for the FoS. The AEODRS is entering Milestone B, and the development of increment 1 (dismounted operations) is now starting.

In addressing interoperability for ground systems, Robotic Systems Joint Project Office (RS-JPO) is utilizing SAE JAUS for messaging (with custom extensions as necessary) and primarily focusing on communications, payloads, power, architecture, and controller. Progress has already been made, with a modeling and simulation demonstration and an Input/Output (IO) Specification Build V1 planned for 2012.

4.6 Summary

We can no longer afford to acquire independent, proprietary unmanned systems that do not leverage interoperability. The lines in the battlespace are blurring, and the need to share information, sensors, payloads, and platforms is real. The fiscal battlespace is also blurring, and vendors must shift strategies to adhere to standards, drive toward OAs, reuse software, and develop robust repositories. The goal is to provide more capable unmanned systems to the warfighter on time, and interoperability will ultimately play a large role in this effort by enabling the composition of novel systems capabilities on a faster timescale. Figure 10 depicts an interoperability path for the future as industry and DoD strive to become more efficient.

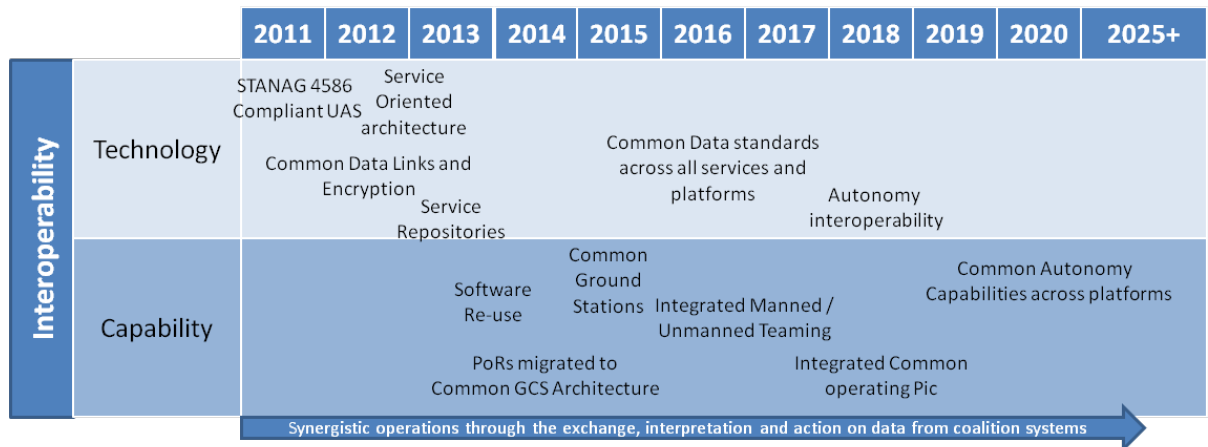


Figure 10. Interoperability Roadmap.

5 AUTONOMY

Dramatic progress in supporting technologies suggests that unprecedented levels of autonomy can be introduced into current and future unmanned systems. This advancement could presage dramatic changes in military capability and force composition comparable to the introduction of “net-centricity.” DoD must understand and prepare to take maximum practical advantage of advances in this area.¹²

5.1 Functional Description

Automatic systems are fully preprogrammed and act repeatedly and independently of external influence or control. An automatic system can be described as self-steering or self-regulating and is able to follow an externally given path while compensating for small deviations caused by external disturbances. However, the automatic system is not able to define the path according to some given goal or to choose the goal dictating its path.

By contrast, autonomous systems are self-directed toward a goal in that they do not require outside control, but rather are governed by laws and strategies that direct their behavior. Initially, these control algorithms are created and tested by teams of human operators and software developers. However, if machine learning is utilized, autonomous systems can develop modified strategies for themselves by which they select their behavior. An autonomous system is self-directed by choosing the behavior it follows to reach a human-directed goal. Various levels of autonomy in any system guide how much and how often humans need to interact or intervene with the autonomous system, and these levels will be discussed shortly. In addition, autonomous systems may even optimize behavior in a goal-directed manner in unforeseen situations (i.e., in a given situation, the autonomous system finds the optimal solution).

The special feature of an autonomous system is its ability to be goal-directed in unpredictable situations. This ability is a significant improvement in capability compared to the capabilities of automatic systems. An autonomous system is able to make a decision based on a set of rules and/or limitations. It is able to determine what information is important in making a decision. It is capable of a higher level of performance compared to the performance of a system operating in a predetermined manner.¹³

5.2 Today's State

In 2010, the USAF released the results of a year-long study highlighting the need for increased autonomy in modern weapon systems, especially given the rapid introduction of UAS. This study, “Technology Horizons,” identified the need for greater system autonomy as the “*single greatest theme*” for future USAF S&T investments. The study cited the potential for increased autonomy to improve effectiveness through reduced decision cycle time while also enabling manpower efficiencies and cost reductions.

¹² USD AT&L *Memo to Chairman, Defense Science Board, Subj Terms of Reference*, 29 March 2010.

¹³ NATO Industrial Advisory Group, Study Group 75, Annex C - Autonomous Operations, 2004.

Autonomous capabilities have been enabled by advances in computer science (digital and analog), artificial intelligence, cognitive and behavioral sciences, machine training and learning, and communication technologies. In order to achieve operational acceptance and trust of these autonomous capabilities in the highly dynamic unmanned system environment, improvement is essential in advanced algorithms that provide robust decision-making capabilities (such as machine reasoning and intelligence); automated integration of highly disparate information; and the computational construct to handle data sets with imprecision, incompleteness, contradiction, and uncertainty.

In response to CCDR needs, the USAF has aggressively expanded UAS capabilities to a target of 65 combat air patrols (CAPs). According to the USAF, 1750 pilots from the Total Force (Active, Guard, and Reserve) are required to maintain these CAPs, which operate around the clock. This increasing manpower requirement is occurring at a time when constrained budgets are limiting growth in Service manpower authorizations. This challenge is not limited to the USAF, but is facing all the military Services. Today's unmanned systems require significant human interaction to operate. As these systems continue to demonstrate their military utility, exploit greater quantities of intelligence, and are fielded in greater numbers, the demand for manpower will continue to grow. The appropriate application of autonomy is a key element in reducing this burden.

Our Program Managers should be scrutinizing every element of program cost, assessing whether each element can be reduced relative to the year before, challenging learning curves, dissecting overheads and indirect costs, and targeting cost reduction with profit incentive—in short, executing to what the program should cost.

—Under Secretary of Defense Memorandum for Acquisition Professionals, Better Buying Power, September 2010

5.3 Problem Statement

The increased manpower to operate unmanned systems is adding stress to the overall workload of the armed forces. This stress highlights the need to transition to a more autonomous, modern system of warfare. The USAF Chief of Staff General Norton Schwartz emphasized the need for more automation in the following statement:¹⁴

[The trend] cannot continue indefinitely. There is a place for automation here that reduces the manpower requirement, both to operate and to process the backend data stream.

— Gen Norton Schwartz, Air Force Chief of Staff

¹⁴ Fontaine, Scott, "Schwartz outlines possible future changes," *Air Force Times*, 30 August 2010.

For unmanned systems to fully realize their potential, they must be able to achieve a highly autonomous state of behavior and be able to interact with their surroundings. This advancement will require an ability to understand and adapt to their environment, and an ability to collaborate with other autonomous systems, along with the development of new verification and validation (V&V) techniques to prove the new technology does what it should. Each of these topics is discussed in more detail below. Advances in autonomy at the system level must proceed with awareness of potential disadvantages and vigilance for unintended consequences, which may include diminished command over parts of the forces structure. Every operation includes rules of engagement, air tasking order (ATO)/special instructions (SPINS), and options of dynamic changes of command direction; and intent must not be traded off. The ability to respond to the unexpected cannot be diminished. For example, dealing with volcanic ash in the atmosphere cannot be reliably predicted at the beginning of an eruption. The ability to respond and avoid affected airspace is an example of a condition that may be difficult for autonomy to address. Implementing autonomy can lead to a loss of human attention to vital oversight in matters having potentially dangerous or lethal consequences. Caution must be used at the system-of-systems level, and constraints applied in some operations in order to allow autonomy in others. Finally, surrendering decision trust to a software-based and self-learning design outside the context of specific operations is a matter of high rigor, and must be examined in the context of organizational-unit and theater CONOPS.

5.4 Way Ahead

Significant advances have been made in autonomy, but many challenges still exist. For relatively static environments and undemanding missions and objectives, rule-based autonomous systems can be highly effective. However, most DoD environments and mission tasks dictate that unmanned systems operate in complex and uncertain environments as well as possess the ability to interact and collaborate with human operators and human teammates. Additionally, autonomous systems need the capability to interact and work together with other autonomous systems, to adapt to and learn from changes in the environment and missions, and to do so safely and reliably. One goal of automation is to leap forward in capabilities using human augmentation. Automated assistance of whatever kind does not simply enhance our ability to perform the task: it changes the nature of the task itself.¹⁵

5.4.1 Transcending to Higher Levels of Autonomy

Autonomy reduces the human workload required to operate systems, enables the optimization of the human role in the system, and allows human decision making to focus on points where it is most needed. These benefits can further result in manpower efficiencies and cost savings as well as greater speed in decision making. Autonomy can also enable operations beyond the reach of external control or where such control is extremely limited (such as in caves, under water, or in areas with enemy jamming or degraded communications). Advances in autonomy will further increase operational capability, manpower efficiencies, and cost savings.

¹⁵ Norman, D. A., "How might people interact with agents?" *Software Agents*, J. M. Bradshaw, Ed. Cambridge, MA: The AAAI Press/The MIT Press, 1997, pp. 49–55.

... the ability to understand and control future costs from a program's inception is critical to achieving affordability requirements.

–Under Secretary of Defense Memorandum for Acquisition Professionals, Better Buying Power, September 2010

While reduced reliance on human operators and analysts is the goal of autonomy, one of the major challenges is how to maintain and facilitate interactions with the operator and other human agents. An alternative statement of the goal of autonomy is to allow the human operator to “work the mission” rather than “work the system.” In other words, autonomy must be developed to support natural modes of interaction with the operator. These decision-making systems must be cognitively compatible with humans in order to share information states and to allow the operator and the autonomous system to interact efficiently and effectively. The level of autonomy should dynamically adjust based on workload and the perceived intent of the operator. Common terms used for this concept are *sliding autonomy* or *flexible autonomy*. The goal is not about designing a better interface, but rather about designing the entire autonomous system to support the role of the warfighter and ensure trust in the autonomy algorithms and the system itself. Table 3 contains the most commonly referenced description of the levels of autonomy that takes into account the interaction between human control and the machine motions.

Table 3. Four Levels of Autonomy

Level	Name	Description
1	Human Operated	A human operator makes all decisions. The system has no autonomous control of its environment although it may have information-only responses to sensed data.
2	Human Delegated	The vehicle can perform many functions independently of human control when delegated to do so. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation.
3	Human Supervised	The system can perform a wide variety of activities when given top-level permissions or direction by a human. Both the human and the system can initiate behaviors based on sensed data, but the system can do so only if within the scope of its currently directed tasks.
4	Fully Autonomous	The system receives goals from humans and translates them into tasks to be performed without human interaction. A human could still enter the loop in an emergency or change the goals, although in practice there may be significant time delays before human intervention occurs.

The single greatest theme to emerge from “Technology Horizons” is the need, opportunity, and potential to dramatically advance technologies that can allow the Air Force to gain the capability increases, manpower efficiencies, and cost reductions available through far greater use of autonomous systems in essentially all aspects of Air Force operations. Increased use of autonomy — not only in the number of systems and processes to which autonomous control and reasoning can be applied but especially in the degree of autonomy that is reflected in these — can provide the Air Force with potentially enormous increases in its capabilities, and if implemented correctly can do so in ways that enable manpower efficiencies and cost reductions.

– USAF Report on Technology Horizons: A Vision for Air Force Science and Technology During 2010-2030, 15 May 2010

5.4.2 Ability to Understand and Adapt to the Environment

To operate in complex and uncertain environments, the autonomous system must be able to sense and understand the environment. This capability implies that the autonomous system must be able to create a model of its surrounding world by conducting multisensor data fusion (MDF) and converting these data into meaningful information that supports a variety of decision-making processes. The perception system must be able to perceive and infer the state of the environment from limited information and be able to assess the intent of other agents in the environment. This understanding is needed to provide future autonomous systems with the flexibility and adaptability for planning and executing missions in a complex, dynamic world.

Although such capabilities are not currently available, recent advancements in computational intelligence (especially neuro-fuzzy systems), neuroscience, and cognition science may lead to the implementation of some of the most critical functionalities of heterogeneous, sensor net-based MDF systems. The following developments will help advance these types of processing capabilities:

1. **Reconfigurability of sensor weighting:** When a heterogeneous sensor net is used for an MDF system, each sensor has a different weight for different applications. As an example, regardless of whether a dissimilar MDF methodology is used to identify an object, an image sensor has much higher weight than radar. On the other hand, when an MDF methodology is used to measure a distance from the sensor to an object, a rangefinder or radar has a much higher weight than an image sensor.
2. **Adaptability of malfunctioning sensors and/or misleading data:** Even if an MDF methodology is used to identify an object, an image sensor cannot perform if it is faced to the sun. Data from the image sensors will either be saturated or need to be calibrated. Additionally, the image sensor data needs to be continuously calibrated if the weather is cloudy and changing because the measured data will be different based on shadows and shading. Therefore, the environment of a heterogeneous sensor net is a key parameter to be considered for design and implementation of an MDF system.

3. **Intelligent and adaptive heterogeneous data association:** Heterogeneous, sensor net-based MDF systems must process different data simultaneously, such as one-dimensional radar signals, two-dimensional imaging sensor data, etc. As the combination of heterogeneous sensors change, the data combination is changed. Therefore, adaptive data association must be performed before conducting MDF and data input to the decision-making module.
4. **Scalability and resource optimization of self-reconfigurable fusion clusters:** The limiting factor of an MDF system is the scalability of self-reconfiguring the fusion cluster to adapt to a changing battlefield and/or the malfunction of one or more sensors. As the number of sensors used for a sensor net increases, the combinatorial number of reconfigurations exponentially increases. To manage such complexity, the MDF system will require a highly intelligent, fully autonomous, and extremely versatile reconfigurable algorithm, including sensor resource management and optimization. Great progress has been made in sensor management algorithms and cross-cued sensor systems, but true optimization is an elusive goal that is currently unavailable. Such capability can be obtained only from intelligent computing technology, which is currently in its infancy.

While robustness in adaptability to environmental change is necessary, the future need is to be able to adapt and learn from the operational environment because every possible contingency cannot be programmed *a priori*. This adaptation must happen fast enough to provide benefits within the adversary's decision loop, and the autonomy should be constructed so that these lessons can be shared with other autonomous systems that have not yet encountered that situation. Yet even in a hostile, dynamic, unstructured, and uncertain environment, this learning must not adversely affect safety, reliability, or the ability to collaborate with the operator or other autonomous systems. The flexibility required of autonomous systems in dynamic, unstructured environments complicates the predictability needed for U.S. commanders to "trust" the autonomy.

"Trust" will be established through robust operational T&E along with safeties and safeguards to ensure appropriate behavior. Complex autonomous systems must be subject to rigorous "red team" analysis in order to evaluate the full range of behaviors that might emerge in environments that simulate real-world conditions. Safeties and safeguards are also required to mitigate the consequences of failures. Because artificial systems lack the human ability to step outside a problem and independently reevaluate a novel situation based on commander's intent, algorithms that are extremely proficient at finding optimal solutions for specific problems may fail, and fail badly, when faced with situations other than the ones for which they were programmed. Robust safeties and control measures will be required for commanders to trust that autonomous systems will not behave in a manner other than what is intended on the battlefield.

5.4.3 Enabling Greater Autonomy in TPED Processes

In addition to C2 processes, traditional TPED processes offer huge opportunities for reducing the degree of human involvement. Near-term developments could introduce a greater degree of automation, ultimately evolving to more autonomous systems. Current TPED processes are manpower intensive. In today's combat environment, most full-motion video (FMV) and still imagery is monitored and used in real time, but then stored without being fully analyzed to exploit all information about the enemy. This challenge is not unique to the unmanned

environment, but it has been exacerbated by the large numbers of ISR-capable, long-endurance unmanned systems being fielded. These systems are collecting great quantities of information and overwhelming current TPED processes. Near-term steps might include implementation of change detection and automatic target recognition software to enable automated cueing that identifies and calls attention to potential threats. Applications of face recognition software could enable high-fidelity FMV to identify individuals of interest. Increased automation in communications intelligence sensors has the potential to identify key words and even specific voices to rapidly alert operators to targets of interest. Ultimately, automated cross-cueing of different sensor types in a networked environment could enable greater autonomy in tasking systems and their sensors to identify and track threats more rapidly.

Increased processing power and information storage capacities also have the potential to change how unmanned systems operate. For example, many current UAS transmit ISR data that is processed and exploited in ground stations. If more processing and exploitation processes can be accomplished onboard a UAS (like the automatic target recognition or communications intelligence examples discussed above), the system can disseminate actionable intelligence for immediate use and reduce bandwidth requirements. FMV ISR, for example, uses roughly an order of magnitude more bandwidth than the C2 data for a UA. By accomplishing more of the TPED process onboard the unmanned system, the link bandwidth can then be focused on transmitting only what's needed, and the overall bandwidth requirements can be reduced.

Today an analyst sits there and stares at Death TV for hours on end trying to find the single target or see something move or see something do something that makes it a valid target. It is just a waste of manpower. It is inefficient!

– Gen James Cartwright, Vice Chairman of the Joint Chiefs of Staff, during remarks to the U.S. Geospatial Intelligence Foundation on 4 Nov 2010

5.4.4 Ability to Collaborate with Other Autonomous Systems

In addition to understanding the environment, unmanned systems must also possess the ability to collaborate through the sharing of information and deconfliction of tasking. Collaborative autonomy is an extension of autonomy that enables a team of unmanned systems to coordinate their activities to achieve common goals without human oversight. This trend in autonomy will continue to reduce the human role in the system.

Autonomously coordinated unmanned systems may be capable of faster, more synchronized fire and maneuver than would be possible with remotely controlled assets. This trend will lead to a shift toward strategic decision making for a team of vehicles and away from direct control of any single vehicle.



The ability to collaborate is one of the keys to reducing force structure requirements. The collaborative autonomy that is developed must be scalable to both larger numbers of heterogeneous systems as well as increased mission and environment complexity. Collaborative autonomy must be able to adapt to the air, ground, and maritime traffic environment and to changes in team members, operators, and the operational environment.

5.4.5 Development of New Approaches to Verification and Validation (V&V)

To ensure the safety and reliability of autonomous systems and to fully realize the benefits of these systems, new approaches to V&V are required. V&V is the process of checking that a product, service, or system meets specifications and that it fulfills its intended purpose. These components are critical in a quality management system such as ISO 9000. Today's V&V processes will be severely stressed due to the growth in the amount and complexity of software to be evaluated. They utilize existing industry standards for software certification that are in place for manned systems (e.g., DO-178B). Without new V&V processes, such as the use of trust audit trails for autonomy, the result will be either extreme cost growth or limitations on fielded capabilities.

Efforts leading to advancements in computational intelligence as well as the appropriate V&V processes are essential. Enhanced V&V technologies would provide both near-term cost reduction and enhanced capabilities for current autonomous systems and would enable otherwise cost-prohibitive capabilities in the future. New autonomous system test and analysis capabilities are also required to assess intelligent single-vehicle and group behaviors. These technological enhancements and policy actions would lead to more effective development, testing, and operations of current and future autonomous systems.

5.4.6 Policy Guidelines to Ensure Safe Operation

Additional measures, beyond V&V, will be required to ensure safe operation of autonomous systems. No V&V process can guarantee 100% error-free operation of complex systems. As software complexity increases, predicting the precise behavior of autonomous systems in real-world environments will be increasingly difficult. Policy guidelines are necessary in order to ensure that if failures or malfunctions occur, or if an unmanned system encounters an unanticipated situation, the system continues to operate appropriately.

Policy guidelines will especially be necessary for autonomous systems that involve the application of force. Current armed, unmanned systems deploy lethal force only in a fully human-operated context (level 1) for engagement decisions. For these systems, the decisions both to employ force and to choose which specific target to engage are made by a human. The United States does operate defensive systems for manned ships and installations that have human-supervised autonomous modes (level 3), and has operated these systems for decades. For the foreseeable future, decisions over the use of force and the choice of which individual targets to engage with lethal force will be retained under human control in unmanned systems.

5.5 Summary

Technological advances in autonomy are critical as the need to field greater numbers of unmanned systems stresses the limited number of available operators. Challenges in the area of

autonomy address not only functionality, but also transparency to the operator, safety, and reliability. Figure 11 provides a vision into the future of the autonomy advances that are required to maintain an affordable force structure and confidently operate unmanned systems in an increasingly complex environment. Initially, autonomy will improve the safe operations of unmanned systems within the increasingly complex environment of military operations as well as reduce operator workload associated with mundane and noncritical processes. Ultimately, autonomy will increase warfighter effectiveness by enhancing unmanned systems capabilities and expanding their capacity to effect results in the battlespace.

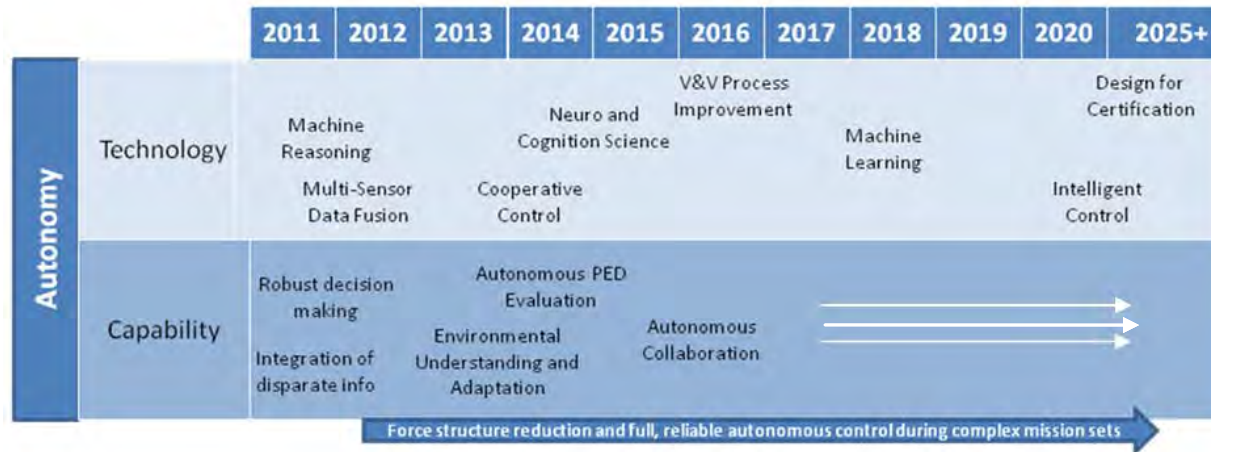


Figure 11. Autonomy Roadmap.

6 AIRSPACE INTEGRATION (AI)

6.1 Functional Description

Over the past several years, UAS have become a transformational force multiplier for DoD. The numbers and roles of UAS have expanded dramatically to meet mission demands, and operational commanders have come to rely upon robust and persistent ISR support from unmanned platforms executing their core missions against hostile forces. DoD UAS require routine NAS access in order to execute operational, training, and support missions and to support broader military and civil demands. UA will not achieve their full potential military utility to do what manned aircraft do unless they can go where manned aircraft go with the same freedom of navigation, responsiveness, and flexibility. Military aviation is a major contributor to the virtue of maneuver for our forces in warfare.

While the force structure continues to grow, the ability to integrate UAS into the NAS has not kept pace. Current access for UAS is greatly limited primarily due to FAA regulatory compliance issues that govern UAS operations in the NAS. DoD UAS operations conducted outside of restricted, warning, and prohibited areas are authorized only under a (temporary) COA from the FAA. Similar issues need to be resolved for access to international and foreign national airspace.

The *DoD UAS Airspace Integration Plan, March, 2011* provides a more comprehensive discussion on the topic of AI. In this plan, DoD provides an incremental approach strategy to provide DoD UAS access to a given operations profile that leads to a full dynamic operations solution. This methodology recognizes that DoD requires access to differing classes and types of airspace as soon as possible and that routine dynamic operations will likely take several years to implement. Figure 12 depicts the six access profiles.

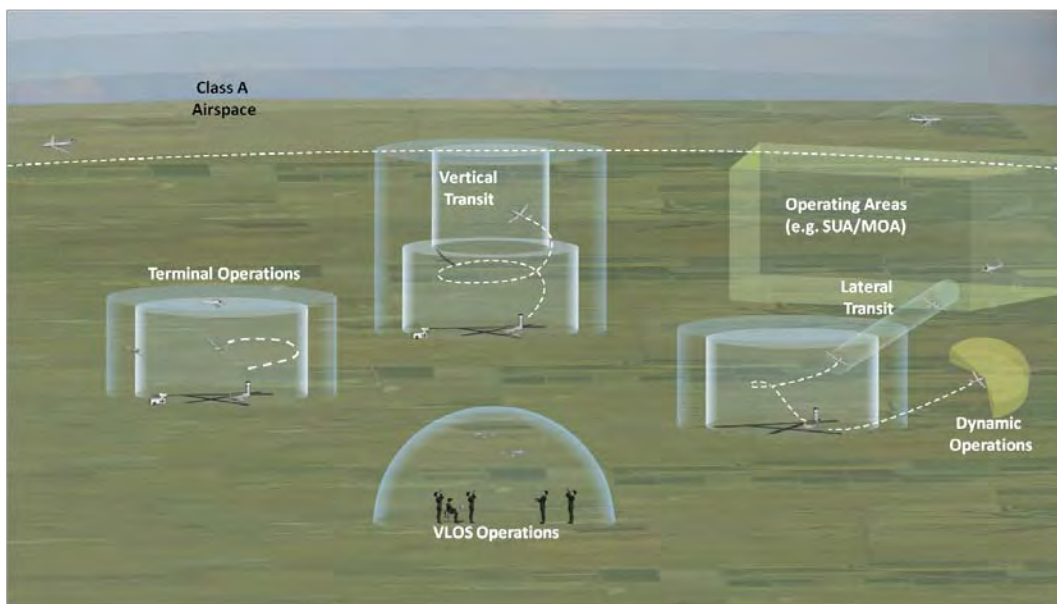


Figure 12. Operational View.

6.1.1 Vision

DoD's vision is to ensure UAS have routine access to the appropriate airspace required to meet mission needs. For military operations, UAS will operate with manned aircraft using CONOPS that make manned or unmanned aircraft distinctions transparent to air traffic services (ATS) authorities and airspace regulators. Having robust UAS AI capabilities for all classes of U.S. airspace is fundamental to flexible worldwide UAS deployment.

NAS Access Requirements

- Aircraft must be Airworthy
- Must be operated by a Qualified Pilot/ Operator
- Compliant with Operating Rules, Standards, and Procedures

... it is vital for the Department of Defense and the Federal Aviation Administration to collaborate closely to achieve progress in gaining access for unmanned aerial systems to the National Airspace System to support military requirements.

– 110th Congress, NDAA for FY09, Sect 1039

6.1.2 Precepts

The 2010 DoD Airspace Integration Plan outlines DoD's approach, which is summarized by four overarching precepts (see right). The U.S. military will use its vast experience to develop the safest, most capable UAS fleet possible. We will strive for maximum compliance with existing regulatory guidance and inform regulatory processes when changes are needed. DoD will fully leverage statutory authorities to design, test, and ultimately certify its UAS in compliance with applicable standards, regulations, and orders. The regulatory and policy changes may be broad in scope to affect multiple Military Departments and Combatant Commands (CCDRs); therefore, UAS AI activities should make every effort to be coordinated prior to engaging with FAA or other external agencies.

Airspace Integration Precepts

- Apply Our World-leading Aviation Expertise to UAS
- Conform Where Possible, Create Where Needed
- Leverage DOD Authorities and Equities
- Engage as One

6.2 Today's State

In order for any military aircraft — manned or unmanned — to fly routinely in domestic and international airspace, three foundational requirements must be met. These three requirements are essential and form the foundation for UAS AI. Title 10 of the United States Code (USC) is the legal underpinning for the roles, missions, and organization of DoD and provides authority for the military departments to organize, train, and equip U.S. forces to fulfill the core duties for national defense. Consistent with this statutory authority and longstanding practice and reinforced by interagency agreements, DoD is responsible for establishing airworthiness and

pilot training/qualification requirements for the military and ensuring rigorous military standards are satisfied.¹⁶ The third and most complex requirement, regulatory compliance, encompasses both internal military department regulations and external FAA and International Civil Aviation Organization (ICAO) flight regulations.



6.2.1 Airworthiness

Airworthiness is a basic requirement for any aircraft system, manned or unmanned, to enter the NAS. The primary guidance for DoD airworthiness certification is found in MIL-HDBK-516B, *Airworthiness Certification Criteria*. This document defines airworthiness as



*“the ability of an aircraft system/vehicle to safely attain, sustain and terminate flight in accordance with an approved usage and limitation.”*¹⁷

Airworthiness certification ensures that DoD aircraft systems are designed, manufactured, and maintained to enable safe flight. Certification criteria, standards, and methods of compliance establish a minimum set of design and performance requirements for safely flying a given category and class of aircraft. The DoD is expanding current military airworthiness guidance to include criteria

that address those component and system attributes that are unique to UA. UAS-unique standards derived from NATO STANAGs (e.g., 4671¹⁸, 4705, and 4703) will be reviewed and incorporated as appropriate.

6.2.2 Pilot/Operator Qualification

The DoD determines where and how it will operate its aircraft, and each Military Department creates the qualification training programs necessary to safely accomplish the missions of that aircraft or weapon system. The standards to train and qualify pilots/operators of UAS will remain under the authority of the Military Departments and appropriate CCDRs. UAS pilot/operator training requires a different skill set from the set needed for flying manned aircraft due to differences such as the means of takeoff, cruising, and landing by visual remote, aided visual, or fully autonomous methods. Therefore, the Military Departments and CCDRs must apply the minimum training standards outlined in CJCSI 3255.01 to their respective training programs to ensure the requisite knowledge, skills, and abilities are addressed appropriately.



¹⁶ Title 10 provisions relating to service authority to organize, train, and equip include 10 U.S.C. Sec. 8062 (Air Force), 10 U.S.C. Sec. 3062 (Army), 10 U.S.C. Sec. 5062 (Navy), and 10 U.S.C. Sec. 5063 (Marine Corps). Multiple service instructions address airworthiness standards, e.g., Air Force Instruction 62-601, dated 11 June 2010.

¹⁷ MIL-HDBK-516B with change 1, *Airworthiness Certification Criteria*, 29 February 2008.

¹⁸ NATO STANAG 4671, Unmanned Aerial Vehicle Systems Air Worthiness Requirements (USAR).

6.2.3 Regulatory Compliance

The Military Departments have a robust process for establishing manned aircraft flight standards and procedures. However, the current ambiguity and lack of definition in national and international regulatory guidelines and standards for UAS make it difficult to know, with consistency or certainty, whether UAS can comply. In fact, some current UAS may already be operating at appropriate levels of safety; however, until the necessary UAS-specific standards, regulations, and agreed-upon compliance methodologies are defined, establishing regulatory compliance for more routine operations is difficult. In the meantime, UAS operations within the NAS are treated as exceptions through the COA process.

While many requirements can be met through the use of existing manned aircraft, many missions are more efficiently and safely accomplished by using unmanned platforms. Technology advancements may be able to help resolve regulatory compliance issues for UA (particularly Title 14 of the U.S. Code of Federal Regulations (14 CFR) 91.113 containing the see and avoid provision); however, the level and complexity of technology required to resolve today's regulatory compliance issues will negatively affect system affordability.

6.3 Problem Statement

The number of UAS in the DoD inventory is growing rapidly. The increase in numbers, as well as the expanding roles of UAS, has created a strong demand for access to national and international airspace and has quickly exceeded the current airspace available for military operations.

6.4 Way Ahead

6.4.1 Methodology

DoD's UAS NAS access methodology includes the array of UAS platform capabilities, required airspace, technology improvement, and implementation activities/products required to attain routine operations within the NAS. This methodology uses an incremental approach to provide DoD UAS access to a given operations profile that leads to a full dynamic operations solution (see Figure 13). This methodology recognizes that DoD requires access to differing classes and types of airspace as soon as possible and that routine dynamic operations will likely take several years to implement.

The profiles, as outlined in an operational view (Figure 12) and DoD's AI Plan, may be used individually to access specific local airspace or integrated together to satisfy additional airspace requirements. Visual LOS operations establish a means to conduct UAS operations in Visual Flight Rules conditions. The terminal area profile is intended to facilitate UAS operations in a confined volume of airspace, such as Class D airspace or near restricted airspace. UAS operating areas, such as special use airspace (e.g., restricted area, or military operations area (MOA)), can be accessed either by flying through a lateral corridor (through Class E) or by vertically ascending to Class A airspace and flying across. While operating areas are limited to restricted or warning areas, MOAs are desirable because they offer a wide variety of airspace spanning 43 states to provide a robust, nationwide UAS training capability without the creation of new airspace.

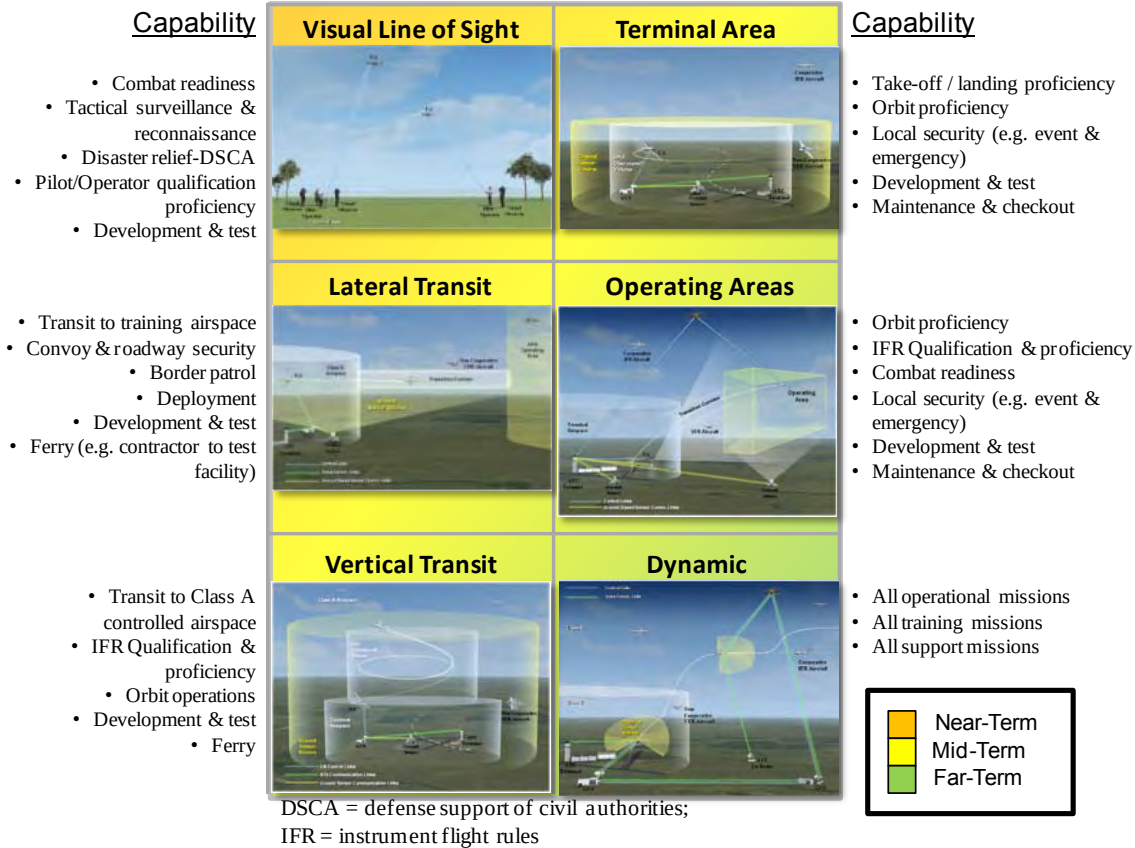


Figure 13. Incremental Approach to Regulatory Compliance.

Plans and programs to enable UAS operations within a profile will be evaluated for joint applicability and NAS access utility. For example, because most of the required near-term airspace for DoD UAS will be in Class D, E, and G, DoD intends to focus much of its near-term resources on addressing this major need.

6.4.2 Policy

Policy agreements can maintain the safety of the NAS while also allowing certain requirements to be fulfilled. In 2007, DoD and FAA signed a Memorandum of Agreement (MoA) allowing limited UAS operations for small UAS below 1200 ft above ground level (AGL) and UAS within DoD-controlled, non-joint-use Class D airspace. The 2007 MoA will be updated periodically, as needed, to allow DoD to incrementally increase access to the NAS. For example, the small UAS special federal aviation regulation is expected to be complete in 2013, but DoD can immediately leverage this work by seeking to incorporate many of the recommendations into an updated DoD-FAA MoA.

The Policy Board on Federal Aviation (PBFA) serves as the DoD liaison with the FAA on federal air traffic control and airspace management. The board provides policy and planning guidance to ensure the Military Departments have sufficient airspace to fulfill requirements. With support from OSD and the Military Departments, the board is working with FAA to update the 2007 MoA.

Where broader issues involve other agencies, the DoD participates in the UAS Executive Committee (ExCom). The ExCom acts as a focal point for senior leaders from FAA, DoD, DHS, and National Aeronautics and Space Administration (NASA) to meet periodically to resolve any policy and procedural disputes and to identify solutions to the integration of UAS into the NAS. The ExCom has established a working group to address COA issues, published a plan to Congress in October 2010, and continues to address specific issues such as collecting and sharing UAS safety data.



6.4.3 Technology

Current UAS are built to different specifications for different purposes; therefore, showing individually that each system is safe for flight in the NAS can be complicated, time consuming, and costly. Routine access cannot happen until DoD and FAA agree to an acceptable level of safety for UAS, and the appropriate standards are developed to meet that threshold. With developed standards, UA will be operationally treated as manned systems, and such treatment will improve interoperability with other systems, cost savings, and development transparency.

Until those necessary UAS-specific standards are established, requirements will be dependent on the individual system and intended flight environment (access profiles). Each system's mission requirements will drive the selection of sense and avoid (SAA) solutions and process for implementation. Ground-based sense and avoid (GBSAA) can provide an initial means to maintain aircraft separation requirements for multiple profiles, while improvements to sensor and automation technology will continue to improve an airborne SAA (ABSAA) solution.

GBSAA efforts are focused on developing methods to provide aircraft separation within a prescribed volume of airspace using a ground-based system that includes sensors, displays, communications, and software. GBSAA solutions will incrementally relieve restrictions on existing COAs and facilitate UAS training and operations in the NAS. This effort is establishing requirements, gathering data, performing modeling and simulation, testing and verifying collected data, and obtaining airworthiness approvals, as appropriate. GBSAA can particularly benefit smaller UAS where other SAA solutions are cost prohibitive.





ABSAA efforts are focused on developing onboard capability to perform both self-separation and collision avoidance that ensure an appropriate level of safety. Current programs have phased validation schedules for due regard, en-route/Class A, and divert/ Class E/G operations as technology innovation and integration allow. GBSAA and ABSAA may be applied as a single or combined solution to some access profiles to maximize safety and/or reduce operational costs.

6.4.4 CONOPS Development

The DoD is developing an AI CONOPS to provide a framework for common UAS practices, procedures, and flight standards in NAS and international airspace. It is intended to standardize UAS access methodologies and procedures, implement appropriate methods for compliance with see-and-avoid requirements, and inform development of an UAS AI Initial Capabilities Document (ICD). It will establish a standard suite of lost-link, lost-communications, and lost-SAA procedures for DoD UAS in all phases of flight. These procedures will help define methods for notification and the appropriate action to either regain link or recover/divert the UA. The CONOPS also provides the operational and procedural construct to employ the access profiles at bases across the United States and to inform the process of basing UAS in locations outside the continental United States (OCONUS).

6.4.5 Requirements Development

The CONOPS, along with the Military Departments' individual location airspace requirements, will feed development of an UAS AI ICD. The UAS AI ICD is intended to identify the financial requirements for UAS integration into the NAS across the United States and OCONUS. As the initial SAA technologies mature through development and validation, they can be applied to the appropriate profiles and documented in the UAS AI ICD. This effort will allow the Military Departments to accurately estimate the costs to operate UAS at any given individual location as needed.

... limited access to airspace is having a negative impact on the unmanned aviation community and many regions of the U.S. that are ready to support UAS industry growth.... over the next 15 years more than 23,000 UAS jobs could be created in the U.S. as the result of UAS integration into the NAS.

– *Aerospace Industries Association. (2010). Total Employment: Annual Calendar Years 1990-2009. Available at AIA website: <http://www.aia-aerospace.org/assets/stat12.pdf>*

6.4.6 Timing of Activities

The DoD is focusing on near-term, mid-term, and far-term activities. This timing allows for immediate improvements in NAS access, while working toward viable long-term solutions.

- Near-term activities address small UAS, DoD-controlled airspace, and operations under COAs. Priority is given to initiatives that reduce COA requirements and streamline the FAA approval process. DoD believes significant near-term improvement in UAS NAS access is achievable through COA, policy, and procedural initiatives.
- Mid-term activities address local airfield and transit operations. Where policy and procedures fall short of achieving the long-term objective of routine access, a significant investment in standards and technology development is necessary. Priority is given to developing validated AI requirements and associated standards and to establishing an SAA capability that will provide NAS access through special rules and policy, new procedures, and use of ground-based sensor technology.
- Far-term activities address most UAS missions in any operating location and airspace to include FAA's Next Generation Air Traffic Control System (NextGen). The end state is routine NAS access comparable to manned aircraft for all DoD UAS.

6.5 Summary

DoD UAS have become a critical component of military operations. Many DoD UAS now require rapidly expanded access to the NAS and international civil airspace to support operations, training, testing, and broader governmental functions.

In order for military aircraft to fly routinely in domestic and international airspace, the aircraft must be certified as airworthy, operated by a qualified pilot/operator in the appropriate class(es) of airspace, and comply with applicable regulatory guidance. DoD exercises sole certification authority for its aircraft and pilots/operators, consistent with authority provided in Title 10 of the US Code.

DoD's UAS NAS access methodology uses an incremental approach to provide DoD UAS critical access to a given operations profile prior to implementing a full dynamic operations solution. DoD's immediate focus is gaining near-term mission-critical access while simultaneously working toward far-term routine NAS access. DoD's efforts will have positive affordability effects by championing utilization of UAS within the NAS. This progress will be accomplished through policy and procedural changes as well as technology and standards development and is thoroughly outlined in the AI Plan. The end state is routine NAS access comparable to manned aircraft for all DoD UAS operational, training, and support missions.



Figure 14. UAS NAS Roadmap.

7 COMMUNICATIONS

“Ongoing operations in Southwest Asia continue to drive the voracious demand for pilots, support personnel and bandwidth above all”

– Col. J.R. Gear, USAF, speaking at recent C4ISR Journal Conference in Washington.

7.1 Functional Description

DoD unmanned systems need a process for operational control and mission data distribution, especially for nonautonomous systems. For some ground and maritime systems, these types of exchanges of information can use a cable for the transmission path, but for highly mobile unmanned operations, the exchange is more likely to use signals sent across the electromagnetic spectrum (EMS) or by other means (e.g., acoustical or optical). The EMS is highly regulated at the national¹⁹ and international²⁰ levels. While numerous over-the-air communication systems have been designed, built, and fielded and have performed reasonably well, others have been fielded in a noncompliant status and have not met difficult operational constraints.

DoD’s desire is to operate unmanned systems in theater or within the United States and its possessions so that communication constraints do not adversely affect successful mission execution. Specifically, DoD must significantly improve communication transmission efficiencies; attain better bandwidth efficiencies; increase transmitter and receiver efficiencies; and acquire communications systems that are of less size and weight, require less power, and provide more efficient cooling to operate.

The operational employment of Unmanned Aircraft Systems requires access to a range of SATCOM capabilities. Planning and budgeting for UAS operations must take into account realistic assessments of projected SATCOM bandwidth (both military and commercial) in a range of operational scenarios. Investments in UAS systems must be matched with appropriate investments in the military and commercial SATCOM capabilities that are required to support UAS operations.

7.2 Today’s State

The state of unmanned systems communication systems differs greatly among the air, ground, and maritime environments. In supporting operations in OIF, Operation New Dawn (OND), and OEF there has been a large number of new sensors and communication systems installed on various fielded unmanned systems. These have significantly increased the amount of data that has been collected, and that is desired to be sent to local and remote warfighters. To

¹⁹ For the U.S. Government, see the National Telecommunications and Information Administration’s *Manual of Regulations and Procedures for Federal Radio Frequency Management*. Washington, DC, January 2008 edition, September 2009 revision (incorporated by reference under 47 CFR 300.1).

²⁰ International Telecommunication Union (ITU), *Radio Regulations*, Geneva, Switzerland. 2007 Edition.

get the needed data to the remote warfighters, the DoD pays significant funds to several commercial large data transmission companies. Many current unmanned systems have experienced the impact of frequency congestion, interference from systems operating in adjacent frequency bands, and the physical limits associated with the spectrum that has been made available.

The following paragraphs describe the current communication environments by domain.

7.2.1 Unmanned Ground Systems (UGS)

Until recently, most unmanned systems utilized several radios: one for data, one for video, and sometimes one for voice. Because of congestion, frequency competition, and regulatory challenges in several theaters, many of these communication systems were redesigned to operate at higher frequencies. However, use of these higher frequencies reduced the operational effectiveness in dense foliage and urban areas.

7.2.2 Unmanned Aircraft Systems (UAS)

Small, hand-carried and/or hand-launched systems (e.g., the Raven) utilize LOS communications, while large aircraft (e.g., the Predator, Reaper, Gray Eagle, and Global Hawk) utilize both LOS and BLOS communications, the latter generally using satellite communications.

Initial small UAS (< 20 lbs) communication systems utilize industry analog designs, but most now utilize the Army-developed digital data link (DDL) system.²¹ The DDL design incorporates aspects of a software-defined radio with the ability to “field-select”²² the frequency band in which to operate, the channel frequency within that band, the bandwidth of each channel, and the radiated power level.²³ Larger UAS operating LOS incorporate the common data link (CDL) that has been mandated for use in ISR platforms.

7.2.3 Unmanned Maritime Systems (UMS)

There are unique challenges related to UMS: dealing with the air water interface, transmission loss communicating underwater, and negotiating the dynamics of the sea surface. Intermittent communications are the norm in maritime systems and multispectral capabilities are utilized to meet communications requirements. Primary tradeoffs to be considered when evaluating a mode of communication for a USV or UUV that supports dynamic tasking, querying, and data dissemination include data rate, processing capability, range, detectability, and negotiating the maritime environment. These are of particular concern for the ISR and the

²¹ Developed by the Army’s Natick Soldier Research, Development & Engineering Center. An alternative DDL for small UAS is also being developed that could use a version of CDL. NATO has developed STANAG 4660, Interoperable Command and Control Data Link for Unmanned Systems (IC2DL), which is based on the DDL.

²² This selection process is not by software but by switches. Moving to software control is being considered during a future upgrade of the DDL.

²³ The USAF Cryptographic Modernization Program Office and the Army developed a prototype encryptor for this DDL.

ASW missions when communication is desired without exposing either the sender or receiver to possible hostile interception.²⁴

7.3 Problem Statement

There are alarming red flags early in this Roadmap's time horizon regarding the amount of data that future UMS sensors will be collecting. How to best deal with that amount of data and distributing the needed information within that data to the right warfighters at the right time will be a major challenge. Left unchecked, sending all that data to local or remote sites will tax current technology and available funding (e.g., COMSAT links). The DoD needs communication technologies and tactics, techniques, and procedures that overcome these limitations and that are agile, robust, redundant, efficient, and affordable. Those needed technologies are discussed throughout Section **7.4 Way Ahead**. However, improved communication transmission technologies alone cannot achieve the necessary capacity. The DoD must pursue a fundamental shift to a future state where we pre-process the collected data, rapidly pass only critical data on to the warfighters, and then store for later retrieval the remaining data that may be needed.

In addition to achieving these technology advances²⁵, their application in UMS needs to meld with overall DoD wireless network communication concepts, meet national objectives for unmanned systems, and properly address regulatory policies and their limitations. All this needs to be done early in the requirements development process so those advances can be incorporated within future UMS.

In particular, tomorrow's UMS will need to utilize technical strategies which can more efficiently deal with extremely large data sets. In managing this data, better data compression, encryption and processing algorithms need to be employed in preprocessing, transmission and data fusion. These strategies also need to mandate efficient use of the spectrum, reduce frequency use overhead, allow for data security and ensure improved clarity of the available frequency spectrum. To support DoD's goals, communication systems need to support multiple frequency bands, limited bandwidth, variable modulation schemes, error correction, data encryption, and compression. All this support, of course, needs to be done so that no electromagnetic interference (EMI)²⁶ is caused within those systems or within other nearby spectrum-dependent systems (SDS).

There are numerous challenges to meeting this goal. First, operating a higher density of unmanned systems within relatively small areas creates increased local data rate demands. Second, size, weight, power and cooling (SWaP-C) are limiting factors on many platforms, for both onboard systems and ground/surface control systems. Third, the fidelity of the communication links must be ensured. Fourth, latency associated with digital systems must be reduced, especially for takeoff and landing of large UAS. These challenges will be exacerbated

²⁴ U.S. Navy Undersea Dominance Roadmap.

²⁵ These advances need to include government ownership of critical data and intellectual property to ensure the best return on our research investment.

²⁶ The development of the resulting on-board and ground stations needs to address EMI hardening and the units tested per MILSTD-464A and MILSTD-461F.

by an expected decrease in available spectrum available due to an increase in the civil²⁷ uses of spectrum, an objective within the Federal Communications Commission’s (FCC’s) National Broadband Plan²⁸ and directed by the White House²⁹. The challenges in attaining this goal include developing, procuring, testing, and fielding communication systems that can operate with greater effectiveness, efficiency, and flexibility even in congested and adversarial environments.

Spectrum testing in unmanned systems today involves communications across a global environment with various levels of spectrum management. The communication challenges require investment in multiple technologies for leveraging communications across the radio frequencies and ultimately the optical spectrum. The impediments to unmanned systems communications are largely restricted to better use of the spectrum through investment in technologies that expand communication efficiencies. The problem today is largely a physics problem, which increases in complexity exponentially as one considers the air, ground, and maritime domain challenges. The testing of cognitive algorithms that can opportunistically leverage communications facilitating advanced mission oversight or multisystem collaboration remains in its infancy.

7.4 Way Ahead

Current DoD policies and guidance stress the need for new systems³⁰ to have a balance among improved interoperability; increased agility³¹; greater adaptability; improved spectral efficiency; compliance with U.S. national, host nation, and international spectrum policies³²; and lower production costs. The ability to update and reconfigure parts of a communication system by software changes (e.g., software-defined radios) has been available for several years. In addition, these systems should conform to a standards-based architecture (e.g., service-orientated architecture) that supports multiple networks to enable rapid and transparent configuration changes without removing the radios from operation. Such multiple-input, multiple-output (MIMO), multicarrier, and multiwaveform capabilities, along with the software control of these functions, are needed within future subsystem developments. Ultimately, it is desired that these reconfiguration changes be done “automatically” so the systems adapt dynamically (Figure 11. Autonomy Roadmap.) in response to sensed changes in the operational environment³³ (> 2020).

The need to support operations in which there are intermittent wireless propagation links has become common place. This support has resulted in increased use of advanced error control coding, MIMO configurations, various path diversity techniques, integrated networking, and data diversity — all to provide improved end-to-end quality of service. Future effectiveness of unmanned communication systems is contingent on continued advancements in antennas,

²⁷ Both in CONUS and OCONUS.

²⁸ FCC’s National Broadband Plan, Washington, DC, 2010.

²⁹ Presidential Memorandum “Unleashing the Wireless Broadband Revolution.” June 28, 2010,

³⁰ This goal includes systems used in networking, communications, electronic warfare, navigation, intelligence, and sensors.

³¹ This goal would include assured and secure communications.

³² See DOD Instruction (DODI) 4650.01, Management and Use of the Electromagnetic Spectrum, Washington, DC, 9 January 2009, and DODI 4630.8, Procedures for Interoperability and Supportability of Information Technology (IT) and National Security Systems (NSS).

³³ Also see Section 5 of this Roadmap.

transmit/receive systems, underwater communications, spectrum considerations, signal processing, network systems, and optical communications. A description of those advancements is given in the following subsections.

... Reinvigorate the industry's independent research and development and protect the defense industrial base.

—Under Secretary of Defense Memorandum for Acquisition Professionals, Better Buying Power, September 2010

7.4.1 Antennas

Communication with highly mobile systems requires high-gain, rugged, and lower cost multidirectional antennas. The larger UAS systems may also use highly focused beams to achieve connectivity with more distant systems.³⁴ Developments in phased array antennas and “smart” antennas (to include combining signals from multiple antennas) could offer an alternative to traditional dish antennas; however, they require tradeoffs among SWaP-C. DoD and industry will need to continue developing such techniques as multifocused and super-cooled antenna systems. The multi-focused systems would permit multiple users to receive information and not rely on point-to-point systems and subsequent relaying of data via other communication systems to local users.

Future antenna systems need to be able to send and receive signals over a broad range of frequencies. Phased arrays are a viable approach. For SWaP-C and low-profile considerations, phased array antennas need to be conformal (e.g., using metamaterial) that will be molded within the vehicle surfaces. The utilization of common apertures has called for the development of new interference mitigation methodologies that minimize co-site interference effects and improve the potential for achieving simultaneous transmit and receive operations within adjacent frequency bands.

7.4.2 Transmitter/Receiver Systems

Current transmitter solid-state power amplifiers (SSPAs) are typically made with gallium arsenide (GaAs) substrate. Gallium nitride (GaN) SSPAs, currently in development, provide significant advantages over GaAs SSPAs. They offer more than double the efficiency of GaAs amplifiers; they increase the amplifier operational bandwidth; and GaN SSPAs may provide for a wider range of frequency of operation. The high transmit efficiency of GaN systems will also reduce the cooling requirements. In order to achieve some of these benefits, the amplifier designs are being enhanced with adaptive operating point control that adjusts to the instantaneous power being demanded from the amplifier. This enhancement significantly reduces the average prime power required by the amplifier by allowing it to effectively turn itself off when not in use, yet adjusting to maintain proper conditions to ensure minimal distortion at higher instantaneous powers. The GaN technologies are currently available for selected frequency bands and will soon

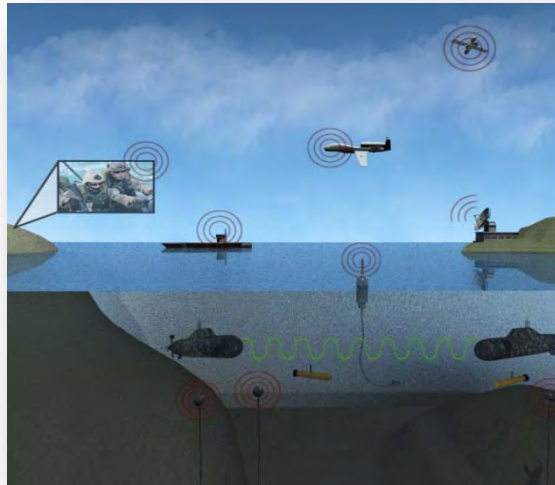
³⁴ Global positioning system (GPS) has been used to aid in this connectivity.

be available for fielding (2014). The amplifiers may also utilize signal-processing-based signal predistortion techniques to compensate for the basic nonlinearity of the amplifier's transfer characteristics.

Instantaneous bandwidth performance and analog-to-digital converter sampling speeds have continued to improve year after year.³⁵ In addition, improvements in integrated chip fabrication methods have allowed for significant miniaturization and reductions in part counts and for various transmit/receive and antenna functions and components to be integrated on a single chip (2013). Fiber optics has been used to speed up the data and signal transfers from and to the antenna and the signal processing hardware (2012).³⁶ Microminiature mechanical device developments should provide smaller size, more flexibility, and greater performance in receiver designs³⁷ (2015). Future developments are expected to provide improvements in reliability and fabrication yields, reduced thermal characteristics, reduced integration complexity, and lower production costs.

7.4.3 Underwater Communications

Ocean dynamics challenge underwater and surface communications and are unique to UUVs and USVs. These systems gain efficiency and effectiveness with real-time, two-way communications that do not undermine mission accomplishment. The Navy's *Undersea Dominance Roadmap* (under development) will identify current and future architectures to link UUVs, distributed netted systems, and tactical platforms. Future developments described in that roadmap will leverage existing technologies and potential new capabilities that will come through the Office of Naval Research S&T research and development efforts.



7.4.4 Spectrum Considerations

U.S. military operations are now occurring in many parts of the world where adequate spectrum is not available. There is a significant increase in the numbers of SDS being deployed by the United States, our partners, and our coalition forces to address current and expected future

³⁵ Lundberg, Kent H., *High-Speed Analog-to-Digital Converter Survey*, MIT Press, 2002.

³⁶ See the DARPA Optical RF Communications Adjunct and the Office of Naval Research's Enabling Capability programs. This application is more for ground-based systems than for airborne systems. This use also significantly minimizes the signal loss and allows more advantageous placement of selected components.

³⁷ C. T.-C. Nguyen, "Microelectromechanical devices for wireless communications (invited)," *Proceedings*, 1998 IEEE International Micro Electro Mechanical Systems Workshop, Heidelberg, Germany, Jan. 25-29, 1998, pp. 1-7.

mission areas. In addition, these SDS collect more information, and missions often require greater bandwidths to send their information directly to warfighters. This latter consideration has been seen within OEF missions where new ISR UAS have included wide area surveillance sensors; alternative spectrum bands have been identified³⁸ to help address the wider bandwidths needed by those systems. Also, mission areas are becoming more spectrally “noisy” because of increasingly cluttered and hostile spectrum environments. As such, a continual demand for improved spectrum efficiency and effectiveness is being placed on all DoD SDS.³⁹ All unmanned systems must complete during their development process a spectrum supportability and risk assessment in accordance with DODI 4650.01 to identify and mitigate regulatory, technical, and operational spectrum supportability. Because national and international spectrum rules and policies can rapidly change,⁴⁰ developers should maintain a close liaison with appropriate DoD spectrum offices before finalizing communication system designs.

The use of LOS datalinks also supports missions where there is a denial of or impaired service to SATCOM systems. Under such conditions, the demand for LOS spectrum will be extended to support the need for improved spectrum use efficiency and effectiveness.

The Defense Advanced Research Projects Agency’s (DARPA’s) Next Generation (XG) project and its follow-on Wireless Network after Next (WNaN) program demonstrated the feasibility of dynamic spectrum access (DSA). DSA offers the ability to change frequency band use based on other adjacent SDS actual use and nonuse of certain bands. The Joint Tactical Radio System (JTRS) program is investigating the feasibility of integrating DSA technologies into its system. The U.S. Army is also considering having WNaN become part of an Army program of record. However, a recent USAF Scientific Advisory Board study said that DSA is far from being proven technology. Developmental challenges include susceptibility to countermeasures, costs of integrating with existing systems, developing standards (including regulatory aspects), and co-site interference (2015).

Alternative technology advances should aid in the spectral efficiency challenge to include internal and external EMI mitigation advances such as coherent signal cancellation, space-time adaptive processing, polarization diversity, and adaptive digital beam forming.

³⁸ OASD NII memo dated March 22, 2011 Subject: Department of Defense (DoD) Common Data Link (CDL) Usage in Operation Enduring Freedom (OEF) Theater

³⁹ All new and modified SDS programs now need to conduct a spectrum supportability and risk assessment prior to Milestone B (source: DODI 4650.01).

⁴⁰ Relatively near-term spectrum usage changes could come from the ITU and its 2011 Worldwide Radiocommunication Conference (WRC); UAS spectrum use is a conference agenda item. Changes in frequency band usage for UAS may also come from the FAA and the ICAO as part of the UAS operations in the NAS airspace and in other nation-states’ airspace.

7.4.5 Communications and Signal Processing

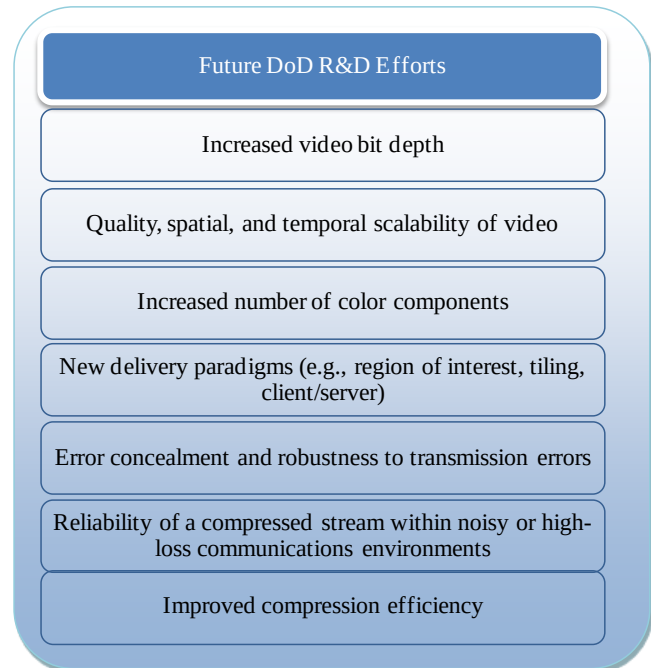
7.4.5.1 RF Waveforms

All ISR systems are to use the CDL waveform specification⁴¹ whenever possible.⁴² A mini-CDL system⁴³ is finishing development to allow CDL usage within smaller platforms than were possible in the past. Candidate future CDL waveform developments include adding a “dial-a-rate” capability for transmission speeds (with multiple bits-per-hertz and operating within the gigabit-per-second range) and a more efficient forward error correction (FEC) coding (both 2014). Also, several UAS program offices are pursuing such performance advances as more efficient CDL waveforms, operation in additional frequency bands, expanded communications security,⁴⁴ low probability of intercept (LPI) or low probability of detection (LPD), improved anti-jam, and greater link throughput. Corresponding improvements in surface and ground stations that receive the CDL signals have also been or are being made. There have also been significant efforts to improve commonality of these systems through the UAS Task Force and its I-IPT.⁴⁵

Future CDL improvements will include, as feasible, the incorporation of advancements being offered by DARPA, industry, and academia. Four of the most appropriate DARPA programs that are being closely followed are the DARPA Interference Multiple Access and Disruption Tolerant Networking programs.

7.4.5.2 Preprocessing

Considering the anticipated large amounts of data projected to be collected by unmanned systems in an environment of limited bandwidth capability, one challenge is determining how much of that data needs to be sent back in near real time to a ground station. There is ongoing interest in addressing how best to select portions of images and to track those portions over time and send back “just” those selected images in near real time. These selection activities are currently being developed within classified TPED programs. As these activities progress, they should be applied in preprocessing efforts onboard



⁴¹ These developments follow DODI 4630.09, DoD Wireless Communications Waveform Development and Management. The currently approved version is Standard CDL (STD-CDL) Rev H.

⁴² The main reason for nonuse would be SWaP-C issues.

⁴³ This effort mostly focused on SWaP-C issues.

⁴⁴ Two cryptographic solutions (one classified and one unclassified) are used currently.

⁴⁵ See Section 4 of this Roadmap.

unmanned systems. Improved preprocessing must be accompanied by sensor and processor miniaturization to reduce SWaP-C so as to maintain the persistent nature of UMS.

7.4.5.3 Compression

Compression techniques have tremendous potential to reduce bandwidth requirements, resulting in lower operating costs and increased operational flexibility. For example, FMV, synthetic aperture radar (SAR), inverted SAR (ISAR), and multispectral images can generate high bandwidth requirements (> 360 Mbit/s data rates). When compressed, the datalink bandwidth requirement could be in the range of only 1 to 30 Mbit/s.⁴⁶ Current compression techniques are described in the motion imagery systems matrix (MISM).⁴⁷ This matrix defines a recommended practice for the simple identification of broad categories of motion imagery systems. The intent of the MISM is to give user communities an easy-to-use, common shorthand reference language to describe the fundamental technical capabilities of DoD/Intelligence Community (IC)/National System for Geospatial Intelligence (NSG) motion imagery systems. The video quality needed for unmanned systems would nominally be MISM levels 4M/4H and 3M/3H. Currently the H.264 standard, which is firmly engrained in the commercial market,⁴⁸ offers twice the performance as Motion Picture Experts Group-2 standard (MPEG-2), and advanced encoding options will give even greater improvements⁴⁹ (albeit with potentially increased encoder latency).⁵⁰ The goal of the United Nations' ITU is for the H.265 standard to provide a chosen quality level at half the bit rate of H.264 (2018). For unmanned applications, future research and development should be undertaken by DoD and industry within areas depicted in the graphic on the right.

Beyond technical compression of all the collected data, there are logical advances that could reduce the amount of information that needs to be sent. This would include incorporation of logical bases for “just” replacing old information about a target’s position with a more recent update, but not resending the unchanging background around the target.

In addition to performance enhancements, compression techniques have tremendous potential to reduce bandwidth requirements and thereby reduce operating costs.

⁴⁶ Operational needs should determine the data rate that should be sent. Commanders in the field should be encouraged to require the lowest possible resolution and other parameters that meet their needs.

⁴⁷ See Motion Imagery Standards Profile (MISP) Recommended Practice 9720d, MISM, Standard Definition Motion Imagery.

⁴⁸ It is widely used within Blu-ray and digital video disk (DVD) systems.

⁴⁹ Over the past several decades, each generation of standardized video compression has provided a halving of the required bit rate for a given quality level relative to the prior generation.

⁵⁰ The latency introduced by some compression schemes can be so great that data links using such compressions cannot be utilized during such critical times as takeoffs, landings, and weapon launches.

7.4.5.4 Encryption

Unmanned systems incorporation of data encryption includes National Security Agency (NSA) Type 1 (for protection of classified and unclassified information) or Federal Information Processing Standards (FIPS) Publication 140-2 certified solutions (for sensitive but unclassified information).⁵¹ Several encryption solutions exist (e.g., Type 1 systems) for protection of unmanned systems communications (see DODI 4660). Numerous other policies and initiatives are under development within the NSA to significantly streamline the certification processes and reduce costs.⁵² Future encryption solutions (2015) will inherently contain Suite B (public) encryption algorithms⁵³ to allow for secure classified information sharing with coalition and friendly forces. Additionally, an increasing number of encryption solutions will be based on such concepts as open standards for remote management; dynamic group keying (to support machine-to-machine information exchanges), common radio and system agnostic cryptographic interfaces (e.g., improving cryptographic component reuse and portability); software-based solutions for protection of classified data;⁵⁴ multifunctional single-chip data-in-transit and data-at-rest encryption; and single-chip all-encapsulated encryption modules (e.g., encrypt/decrypt/random key generation/key management).

7.4.5.5 Multiple Input, Multiple Output (MIMO) Systems

MIMO is a proven technology and is currently being used in commercial fourth generation (4G) wireless systems which have standards calling for a minimum of 100 Mbps for train and car speeds and 1 Gbps for stationary and walking speed.⁵⁵ MIMO combines information theory, FEC coding, signal processing, propagation theory, and consequently the mathematics behind MIMO and space-time coding is complicated. MIMO would utilize multiple paths (although not necessarily independent) with lower data rates on each path; apply space-time coding and capacity optimization to achieve a total high data rate mission; apply power saving to jammer margin; and evaluate performance in benign and stressed conditions.

With further improvements in E-discovery, interface design, and adaptive protocols, self-forming and self-healing mesh networks may enable unmanned systems to operate in multi-platform, multi-sensor type networks.

7.4.5.6 Protected Communications

In general, unmanned systems have been predominantly operated in benign environments. However, efforts are addressing improvements that are required to enable such systems to have assured and secure communications when operating in contested environments. These efforts leverage LPI, LPD, and Anti Jamming (AJ) activities that are underway in other communication systems developments. When moving UMS operations into contentious environments, a

⁵¹ Source: Memorandum from NII, Subject: Cryptographic Methods for Protection of Unmanned Aircraft (UAS) Wireless Communications, 6 August 2003.

⁵² Management Directive 17, (U) Requirements for the Pilot Implementation to Develop Information Assurance Government Off-The-Shelf (GOTS) Secret and Below (SAB) Products and Commercial Solutions for Classified.

⁵³ CNSSP 15, dated March 2010.

⁵⁴ Ongoing efforts by NSA/I851.

⁵⁵ The conditions in UAS applications are much different than those for commercial cell phones.

classified System Threat Assessment Report needs to be developed such that the appropriate LPI, LPD and AJ techniques are selected for incorporation into the system's design. LPD generally seeks to hide specific mission activities and involves techniques such as low power, spread spectrum, pulsed transmissions and/or directional antennas. Certain aspects of DSA could also benefit LPD. A key technique for LPI is the use of bit cover sequences within waveforms. AJ techniques include incorporating randomization at the protocol level and frequency hopping. Some aspects of DSA software implementation could offer some AJ protection.

7.4.6 Network Systems

Networking of multiple unmanned systems may be necessary to better ensure connectivity of the systems in non-LOS, urban, hostile, and/or noisy EMS environments to relay or transfer the collected information. One such concept under development is within the DARPA's LANDroids program,⁵⁶ which calls for the deployment of small, inexpensive, smart robotic radio network relay nodes that can leverage their mobility to coordinate and move autonomously. It seeks to demonstrate the capabilities of self-configuration, self-optimization, self-healing, tethering, and power management. Another concept would be the application of service-orientated architecture approaches to future network configurations.

7.4.7 Optical Communications

The application of lasers in unmanned systems communications could provide increased target detection capabilities, improved anti-jam performance, and decreased EMI within the communication subsystem. Optical communication systems are hampered by atmospheric absorption challenges, yet they offer far greater bandwidth (measured in gigabits-per-second) capabilities. LOS optical links have been successfully demonstrated at link ranges in excess of 50 km. Applications could apply to fixed locations and in air-to-air and ship-to-ship scenarios. Theoretical estimates indicate that air-to-ground links are feasible at rates up to 100 Mbit/s for link slant ranges up to 100 km, depending upon atmospheric conditions. Due to the extreme narrow beamwidth of such systems, maintaining pointing accuracy to and from a moving unmanned system will be a major challenge (> 2020).

7.5 Future Trends

Based on the force multiplier that unmanned systems have provided to our combat troops, it is expected that there will be a continued and increasing demand for supported capabilities communication systems. Those demands will include such capabilities as a single operator conducting more real-time analysis of multiple situations, while the unmanned system performs many of its assigned functions autonomously. Future communications equipment will need to be simple plug-and-play payloads that are easily, quickly, and cost-effectively modified, updated, and/or upgraded.

⁵⁶ Source: <http://www.darpa.mil/ipto/programs/ld/ld.asp>.

Future communications equipment will need to be simple plug-and-play payloads that are easily, quickly, and cost-effectively modified, updated, and/or upgraded.

7.6 Summary

There is tremendous worldwide competition for a finite amount of bandwidth. Concurrently, there is an increased demand for our unmanned systems to provide greater resolution, more persistent coverage, and continuous information flow. Technology supporting physical and software advances, and a fundamental shift in how we process and move vast quantities of data must be used to help overcome these conflicting requirements. Figure 15 provides a glimpse into the future capability and technologies we can expect throughout the course of this Roadmap.

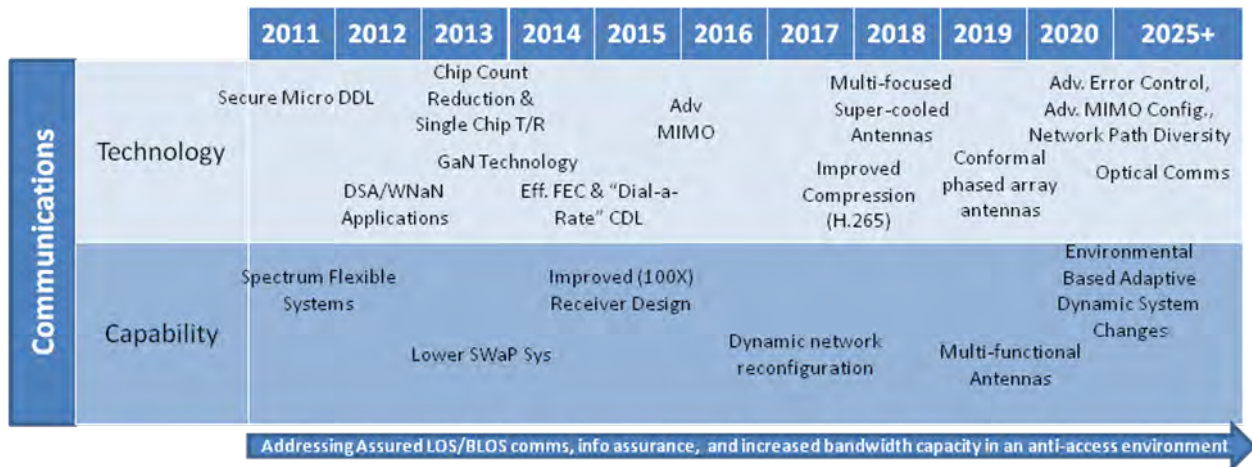


Figure 15. Communications Roadmap.

8 TRAINING

8.1 Functional Description

Training is a critical link in delivering warfighter capability. DoD can acquire and deliver the most technologically advanced piece of machinery, but if the operators, maintainers, and support personnel are not properly trained, there is no warfighting capability. The criticality of this fact is emphasized by the requirement for acquisition program managers to “work with the training community to develop options for individual, collective, and joint training” as part of the acquisition process.⁵⁷

Training is a learning process that involves the acquisition of knowledge, sharpening of skills, concepts and rules, or changing of attitudes and behaviors to enhance performance. Once initial training is complete, proficiency is maintained through continuation and Joint training. Unmanned systems present a unique training challenge due to the following factors:

- Availability of training areas/NAS integration.
- Frequency spectrum management.
- The rapid proliferation of numbers and types of unmanned systems in response to wartime demand.
- Differing organizational perspectives on vehicle operator qualifications, sensor operator qualifications, and support personnel requirements across the growing number of systems in all classes of UAS, UGS, and UMS.
- The reality that most USAF day-to-day continuation training is accomplished under in-theater combat conditions due to the high demand for UAS assets in real-world contingencies. This trend provides limited opportunity for the USAF to integrate its unmanned systems in pre-deployment training as the Army and USMC routinely do.
- Lack of operator interoperability and universal design standards for unmanned systems control stations.
- Lack of formalized joint tactics across the Services.

8.2 Today's State

As unmanned systems have matured and acquisition programs of record have emerged in all Services, a concerted effort has been made to ensure, wherever practical and possible, that the Services share logistics costs and burdens to include training and training systems. To date, many success stories can serve as a template for moving toward the vision of maximum joint training standard(s) for unmanned systems:

- USMC and Army personnel operate a joint Shadow UAS qualification course at the Army's training facility in Fort Huachuca, Arizona. While the Navy does not operate

⁵⁷ DoD Instruction 5000.02 Operation of the Defense Acquisition System, December 8, 2008, p.61.

Shadows, Navy operators and maintainers were asked to help bridge a high-priority capabilities gap. This task was accomplished with no change in training hardware and software, simulation, or practical hands-on training. Navy personnel successfully deployed the Shadow system.

- The Chief of Staff of the Air Force and the Chief of Naval Operations signed a MoA to better utilize joint efficiencies in the Air Force Global Hawk and the Navy BAMS UAS programs. The goals of the working group are transparency between systems and a common work environment for both USAF and Navy operators.
- Army and Navy/USMC personnel share Raven B training and equipment, including maintenance requirements and GCSs.
- The JUAS COE⁵⁸ developed joint CONOPS, training qualification standards, and Tactics, Techniques, and Procedures for UAS.

Despite these success stories, given the DoD mandate to maximize training procedures and standardization for unmanned systems, the current state of unmanned systems training is still very much a work in progress.

The need for a comprehensive UAS training strategy was highlighted in UAS training workshops held in July and November 2009, hosted by the Office of the Deputy Assistant Secretary of Defense for Readiness, Directorate for Training Readiness and Strategy (ODASD(R)TR&S). The workshops were attended by all four Services, CCDRs, OSD, and Joint organizations involved with UAS issues. Additionally, a recent Government

Provide soldiers and leaders the ability to excel in a challenging and increasingly complex future operating environment by developing tools and technologies that enable more efficient and effective training through live, virtual, constructive and mixed venues. Future training must enable the future force to impart more skills, faster, at lower cost and with greater retention than currently achievable. Soldiers and units must be able to be trained using non-traditional home station training techniques and technology and train prior to employment. Future training must enhance and account for individual proficiencies and learning rates (i.e. outcome based training). Future training and leader development must be completely adaptable and scalable to cover the full spectrum of operational challenges facing the Soldier.

– *Capability Gap/Deficiencies, Robotic Systems Joint Project Office Unmanned Ground Systems Roadmap, July 2009*

Accountability Office report recognized the lack of UAS training planning and called for the development of a DOD results-oriented strategy to resolve challenges that affect the ability to train personnel for UAS operations.⁵⁹

⁵⁸ JCOE is being disbanded June 2011 and its tasks are being transferred to the Joint Staff and UAS Task Force.

8.3 Problem Statement

As forces drawdown in theater and redeploy, the Services will require comprehensive continuation and Joint-forces training in the peacetime environment at beddown and selected Joint-training locations. Failure to prepare for this eventuality will result in a loss of combat gained experience.

8.4 Way Ahead

The ODASD(R)TRS is leading efforts to develop a comprehensive DoD UAS training strategy. The strategy will leverage the skills and expertise of each organization and build on foundational efforts already completed or underway within the Services. The study will investigate and assess the adequacy of existing and forecast joint, Service, and CCDR UAS plans and programs that identify and describe qualification, continuation, and joint training requirements and CONOPS. The strategy will identify and describe individual, unit, and large force training requirements of all groups of UAS. The result will be a UAS Training Roadmap that guides UAS training shortfall and mitigation analyses, provides UAS training recommendations, and proposes investment considerations for the UAS community. The UAS Training Roadmap will serve as a companion piece to this Unmanned Systems Roadmap to provide a total look at efforts related to delivering UAS capabilities to the warfighter.

Intuitively, some issues that will need to be addressed in the future include:

Policy: As attention shifts more towards day-to-day continuation training and UAS are further integrated into the NAS, unforeseen disconnects in the ability to train will need to be addressed in policy.

Education: UAS need to be habitually integrated into the kill chain in training scenarios. Commanders must be educated on the use of UAS as combat resources, and learn how to train with these relatively new assets. Tactical, Operational, and Strategic level UAS and ISR doctrine should be included in appropriate professional military education courses of instruction. Issues involving operator currency, flight minimums, and continuation training requirements must be learned and opportunities to train must be emphasized during home station training, combined exercises, and Joint Combined Training Center rotations.

Training Automation and Simulation: Rapidly expanding weapons systems capability requires associated expansion in training simulation. This expansion will need improved simulation fidelity and integration with live platforms for both effective/efficient use of resources. This will require improvements in training environments and classroom courseware.

Basing and Acquisition: As training requirements are defined, existing capabilities at proposed basing locations must be assessed against that which must be acquired to provide effective training.

⁵⁹ GAO-10-331, UNMANNED AIRCRAFT SYSTEMS: Comprehensive Planning and a Results-Oriented Training Strategy Are Needed to Support Growing Inventories, March 2010.

... UAS operators advised that the use of simulation is critical to their preparation for combat. UAS simulation is so accurate and realistic that, specifically for the Shadow UAS, it is hard to tell the difference between the simulator and actual flight.

– SFC Brian Miller, UAS Standardization NCO, Directorate of Evaluation and Standards, USAACE, Fort Rucker

The majority of flight training is simulation.

– SSG Brian Morton, 15W UAS Instructor/Standardization NCO, UAS Training Battalion, Fort Huachuca

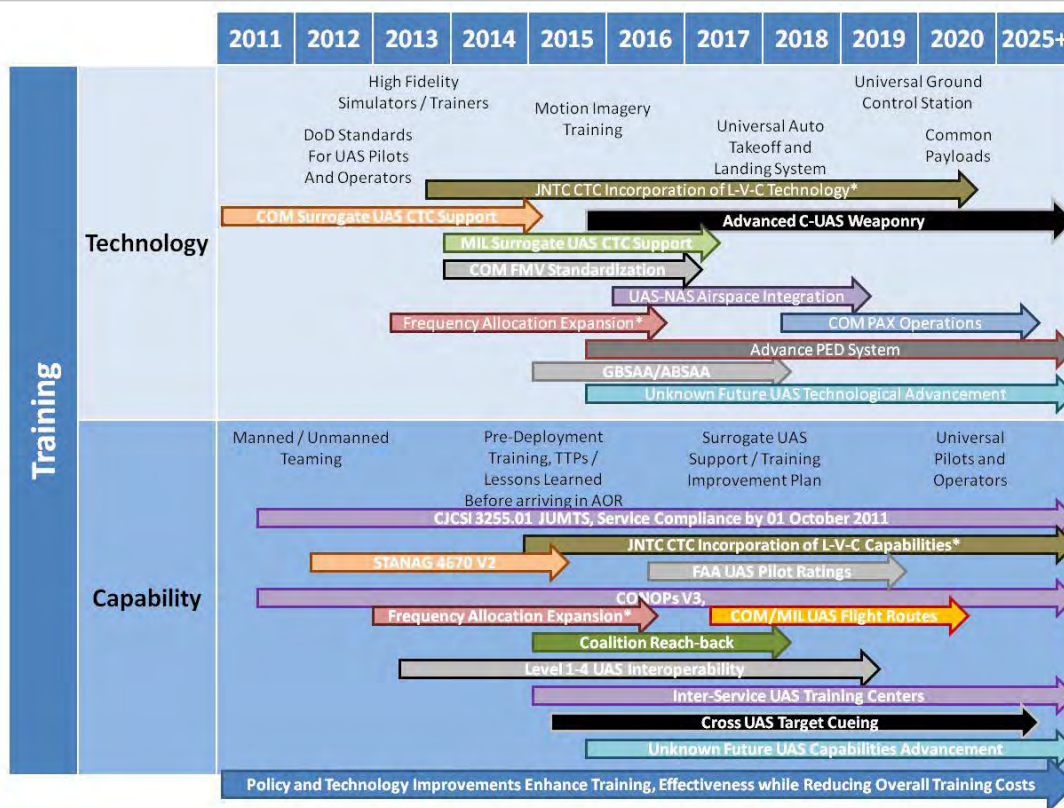


Figure 16. Training Timeline is notional. A DoD UAS Training Strategy is currently in development that will add specificity once developed.

9 PROPULSION AND POWER

9.1 Functional Description

The dramatic increase in the development and deployment of unmanned systems across the entire spectrum of air, ground, and maritime mission requirements has led to a concurrent increase in the demand for efficient, powerful, often portable, and logistically supportable solutions for unmanned system propulsion and power plant requirements.

For the purpose of this section, propulsion and power consist of the prime power to provide thrust and electrical power conversion, management, and distribution necessary for the operation of the electrically driven subsystems required to perform an unmanned vehicle's mission.

9.2 Today's State

A wide array of propulsion systems is used in unmanned systems, including combustion engines powered by heavy fuel or gasoline, jet engines, electric systems, fuel cells, solar power, and hybrid power systems. These propulsion systems can be divided into three groups according to vehicle size and mission: turbine engines, internal combustion, and electrical. The thresholds are not simple or clean cut, but are highly dependent on mission goals. Some of the parameters taken into consideration to determine the optimum propulsion system include size, weight, airflow, range, efficiency, and speed. Similarly, numerous power systems are in use, including batteries, engine-driven generators, solar power and hybrid systems.

The T&E of propulsion and power is critical as we consider a world of declining energy reserves and the strategic initiatives in alternative energy being made by the DoD.

9.3 Problem Statement

Endurance is perhaps one of the most compelling aspects of unmanned systems. While power and propulsion systems are much improved over comparable manned systems, the search continues for even more efficient systems to provide greater endurance, speed and range such as the X-51A Scram Jet shown in Figure 17 preparing for first flight.



Figure 17. X-51A Scram Jet.

9.4 Way Ahead

9.4.1 Propulsion

A primary long-term goal in aircraft propulsion is to reduce system specific fuel consumption by more than 30 percent over (current) gas turbine engines.... Technical challenges being pursued include efficiency, high-overall-pressure-ratio compression systems; variable-cycle engine technologies; advanced high-temperature materials and more effective turbine blade cooling; and techniques to more efficiently recuperate energy while satisfying thermal and power requirements.

– The National Plan for Aeronautics Research and Development and Related Infrastructure

These challenges are currently being addressed for UAS applications under the highly efficient embedded turbine engine (HEETE) and efficient small-scale propulsion (ESSP) products, which are part of the Versatile Affordable Advanced Turbine Engines (VAATE) Program.

HEETE will demonstrate engine technologies that enable fuel-efficient, subsonic propulsion that supports future extreme endurance and range requirements with embedded engines incorporating complex inlets and exhausts. Covering the thrust class of 20,000 to 35,000 lbs, HEETE has two challenges: packing a high-bypass engine internally and delivering large amounts of electrical power regardless of throttle or flight condition. The HEETE design provides very small, high-powered cores to enable high bypass within the diameter constraints of an internally packaged engine. The propulsive efficiency is provided by highly efficient fans designed with the distortion tolerance needed to run behind complex inlets. The HEETE cores run at impressive pressure ratios, greater than 2.3 times the current state-of-the-art, and such ratios enable high tolerance of auxiliary power at high-altitude, long-endurance (HALE) altitudes. See Figure 18 HEETE cutaway view.



Figure 18. Highly Efficient Embedded Turbine Engine (HEETE).

ESSP will cover a full spectrum of technologies for propulsion systems for vehicles ranging from 100 to 2500 lbs. These products promise game-changing system capabilities. The S&T challenge to meet the ESSP goals is the simultaneous combination of high power density with high efficiency (low specific fuel consumption) in a design space not typically addressed by either gas turbine or piston engine systems (see Figure 19. Efficient Small-Scale Propulsion (ESSP).).

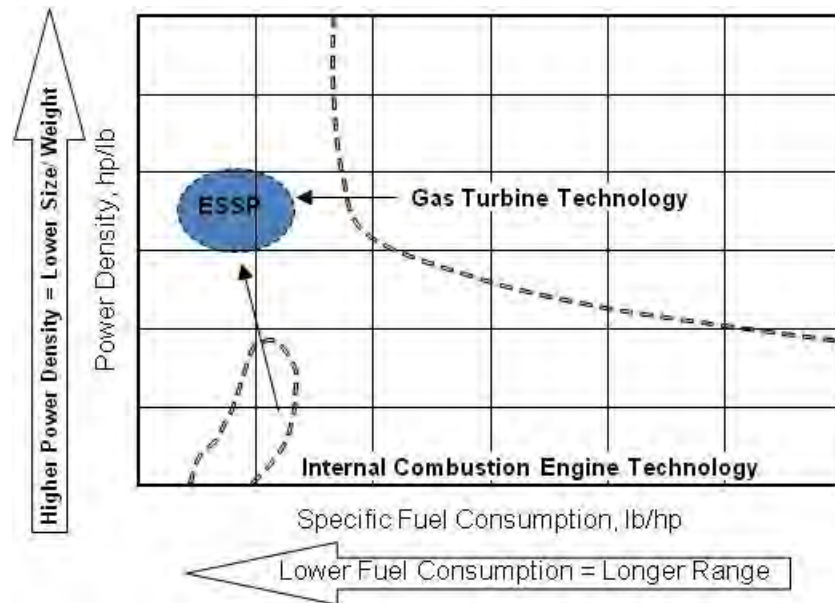


Figure 19. Efficient Small-Scale Propulsion (ESSP).

ESSP will conduct various demonstrations leading to reduced specific fuel consumption (SFC), increased power density, and a heavy fuel consumption capability. These demonstrations include a ducted fan, a nutating engine, a heavy fuel engine conversion, and a recuperator. ESSP is also designing and rig-testing high pressure ratio compressors and high temperature capable turbine concepts aimed at long-term capability.

The ducted fan is the most complex of the near-term demonstrations. The two main technologies to be demonstrated are the high-bypass geared ducted fan and the variable turbine nozzle. The test demonstrates the capability to run the high-bypass ducted fan with airflow from two different distributed core gas generators for maximum power during takeoff and maneuvering and then turning off one core gas generator, as a variable cycle feature, at cruise to cut the fuel consumption (conventional high-bypass turbofans would have to pull back the power setting to attain cruise condition, and this method would decrease engine speed, reduce the pressure ratio, and decrease component efficiencies resulting in increased SFC). The remaining core gas generator used to drive the ducted fan at cruise condition continues to operate at its design point for best cycle SFC. The variable turbine nozzle matches the airflow changes to maintain efficient turbine performance and drive the ducted fan.

The nutating disk engine leverages small business innovation research (SBIR) contracts for both the 4-inch and 8-inch disk engines. Both engines utilize the OSD SBIR-derived advanced microcomponents to enable engine performance potential. The major technical challenges are the

development of micro-fuel injectors and radial engine seals and the understanding of the thermodynamics process. Both sizes of disk engine have undergone initial testing and show a significant increase in power density, to 1.38. The nutating disk is scalable to multiple UAV platforms by scaling the disk size.

The heavy fuel conversion engine, i.e., the Rotax used in the Predator, runs on aviation gasoline (AvGas, 100 octane). The Rotax concept demonstration is aimed at running the engine initially with lower octane fuels and ultimately with JP-8 heavy fuel. Engine testing has been completed successfully with 70 octane fuel. Although octane level is not specified for JP-8 fuel, fuel analysis to date has shown variations between a 20 to 50 octane level. Testing is on-going to demonstrate the operation of the Rotax engine on JP-8 fuel with targeted completion by the end of 2010. In parallel, there are SBIR efforts working to convert the Shadow UEL AR-741 engine to JP-8 fuel. Conversion efforts are aimed at maintaining engine performance levels while operating with JP-8 fuel.

The WTS126 turbo generator, developed by Williams International to drive the General Motors electric car, has a highly efficient recuperator, but is too heavy and large for installation into a flight vehicle. VAATE II studies indicated that a less efficient recuperator appeared to be the best balance among performance, size, and weight for a flight vehicle application. The WTS126 is an alternative heavy fuel propulsion system candidate for the Shadow. Testing and evaluation of the baseline WTS126 and the version with the less efficient flight weight recuperator are both underway.

For smaller platform applications, fuel cells offer an attractive alternative for internal combustion engines as field power generators, ground vehicle and aircraft auxiliary power units (APUs), and primary power units for small UAS. Fuel cells are devices that electrochemically combine fuel and air to produce high-quality electrical power. Because these systems do not generate power via combustion processes, they offer significantly lower SFC rates relative to advanced heavy fuel engines or diesel power generators (see Figure 20).

Solid oxide fuel cell (SOFC) systems represent a compelling power system option due to their high efficiencies, fuel flexibility, and low audible signature. Compared to other fuel cell approaches, the thermal environment and conductivity mechanism in SOFCs allow for a considerable improvement in fuel tolerance and provide a path forward for electrochemical logistic fuel operation.

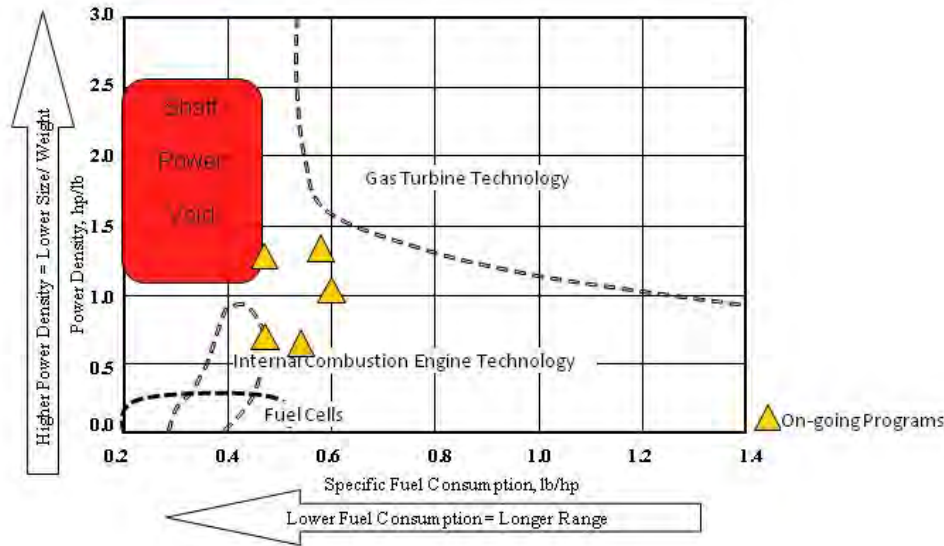


Figure 20. Fuel Cell Efficiency.

9.4.2 Power

Power sources are critical enablers for all of the desired unmanned systems capabilities. Improved power sources will have to be compact, lightweight, and reliable; provide enough power for the desired mission; and satisfy a full range of environmental and safety requirements. Design of power sources must be optimized for specific platforms and use profiles. Depending on the platform and mission requirements, applicable technologies may include energy harvesting (e.g., photovoltaic), electrical energy storage devices, fuel cells, and generators. It may be attractive to hybridize two or more of these technologies depending on the expected use profile. To implement these hybrid systems, the development of the proper control schemes must also be conducted. Recently, there has been a lot of effort invested to improve the power density of power generation systems with very good progress, but work is still needed to improve other power systems critical metrics. Some of these needed metrics and improvements are life, reliability, efficiency, optimized performance over varying engine speed, wide temperature range, production variability, control strategy, and parameters that capture the fact that unmanned subsystems typically do not have the redundancy of manned systems. Early scrutiny of the vehicle design will lead to improved power management. Form factor, materials, autonomy in sensor usage and route planning, and consideration of the undersea physical environment will minimize the energy demands and give back energy to extend the endurance or meet other mission goals.

Advances in mission equipment are providing much greater capabilities, but at a cost of greater demand for electric power, which results in greater power extraction from the engine. Power-sharing architectures allow for tailoring the source of power generation to minimize the cost in fuel burn. For example, if low-pressure (LP) power extraction is more economical than high-pressure (HP) power extraction, then the SSPCs can be turned on to power the bus that was previously powered by the HP-driven generator. Engine power extraction technologies related to power sharing between the HP spool and LP spool promise to provide significant benefit to

bridging the gap between the platform power requirements and the engine power extraction limitations. Additionally, LP power extraction promises to provide improvements to SFC for overall air vehicle energy efficiency. Some of the key technologies needed to implement a power-sharing architecture are reliable power management control logics, high-power high-speed solid-state power controllers (SSPCs), a modulating generator control unit (GCU), and high-capacity electrical accumulator units (EAUs).

The HP GCU can be used to reduce the HP generator output and thus in a similar manner reduce the load on the HP spool to allow the LP generator to fulfill the power demand. The EAUs will be used to support radar peak-power demands and the power demands of short-duration, defensive-directed energy weapons.

9.4.3 Future Opportunity

Work is still needed to demonstrate the shaft power void. However, the large-engine approach of high overall pressure ratios (going to typical small-engine-corrected flow levels) is not available to small engines because of the physical size constraints of turbomachinery. Therefore, nontraditional configurations need to be emphasized to achieve the next level of capability.

Concerning battery chemistries and fuel cells, in the near term (up to 5 years), incremental power and energy performance improvements will continue to be made in the area of rechargeable lithium ion batteries. Lithium ion batteries will see broader military and commercial application, and significant cost reductions will be made as the manufacturing base matures. Near-term availability of small, JP-8 fuel-compatible engines is expected. There is mid-term (5 to 15 years) potential for significant incremental performance advances through the discovery and development of alternative lithium ion chemistries. Mid-term development of fuel cells with moderate power levels (100 W class) will begin to be introduced based on low-weight hydrocarbon fuels (e.g., propane). The technical feasibility of heavy hydrocarbon-fueled (e.g., JP-8) fuel cell systems will be proven at the kilowatt class. In the long term (beyond 15 years), there is the potential for revolutionary improvements through the discovery and development of completely new battery chemistries and designs. Figure 21 charts a course for power and propulsion capabilities and technologies.

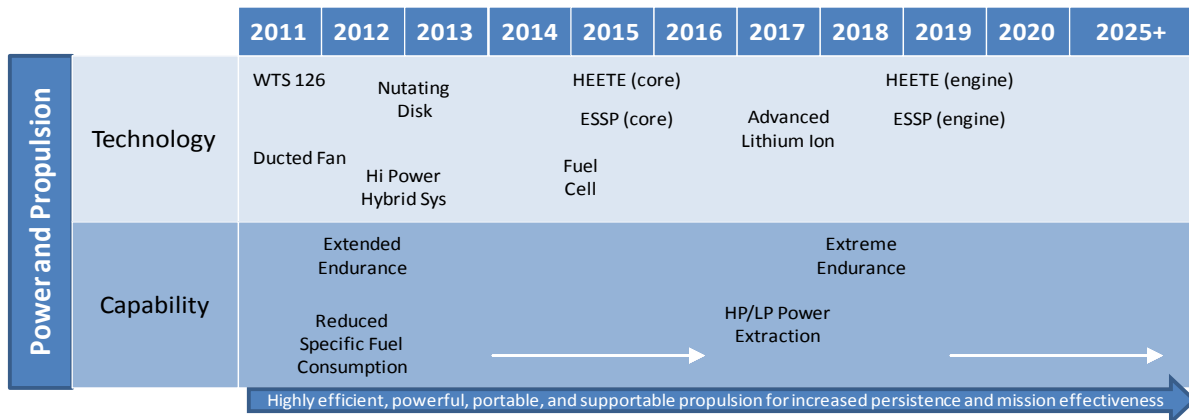


Figure 21. Propulsion and Power Roadmap.

10 MANNED-UNMANNED (MUM) TEAMING

10.1 Functional Description

For this discussion, MUM teaming refers to the relationships established between manned and unmanned systems personnel prosecuting a common mission as an integrated team. More specifically, MUM teaming is the overarching term used to describe platform interoperability and shared asset control to achieve a common operational mission objective. This term also includes concepts of “loyal wingman” for air combat missions and segments of missions such as MUM air refueling. This capability is especially vital for missions such as target cueing and handoff between manned and unmanned systems, where the operators not only require direct voice communications between the participants, but also a high degree of geospatial fidelity to accurately depict each team member’s location with regard to the object being monitored.

MUM teaming was first employed in the late 1960s when the USAF flew AQM-34 equipped with Maverick missiles from airborne C-130 aircraft. Over the intervening years, other experimental UAS were flown from manned aircraft and during the Predator ACTD from a submarine. In 2002, the USAF demonstrated the ability to fly the MQ-1 from a flying C-130 also equipped with a FMV camera to prove a rapid, small-footprint deployment capability, and the ability to cooperatively prosecute targets with onboard and off-board systems. The Army also conducted MUM demonstrations beginning with the Airborne Manned/Unmanned Systems Technology (AMUST) Demonstration in 2001 with a follow-on Hunter Standoff Killer Team (HSKT) ACTD in 2006. During that demonstration, an AH-64D executed level of interoperability (LOI) 4 control of a RQ-5B Hunter UAS during a live fire exercise where Apaches lased for their own Hellfire missiles with the Hunter payload.⁶⁰ At these demonstrations, the Army Aviation Applied Technology Directorate successfully integrated a Mobile Commander’s Associate⁶¹, including UAS control, Link 16, and other various data links, into an Army airborne C2 system. This integration enabled an airborne C2 system operator located in a UH-60 Black Hawk helicopter to control a Hunter UAS and its sensor, for the first time, as well as send and receive tactical information in flight between strike aircraft such as the FA-18, and reconnaissance aircraft such as JSTARS.⁶² To date, each of the demonstrations merely changed the location of the control of the vehicle off the ground. This



⁶⁰ “Hunter Standoff Killer Team Successfully Tests Military Interoperability,” 16 September 2005, <http://aero-defense.ihs.com/news/2005/navy-air-systems-link-16.htm?WBCMODE=presenta>.

⁶¹ “Mobile Commander’s Associate (MCA), Lockheed Martin, USA”, <http://defense-update.com/products/m/mca.htm>.

⁶² Colucci, Frank, “MUM’s The Word,” *Rotor & Wing Magazine*, 1 November 2004, <http://www.aviationtoday.com/rw/military/attack/1817.html>.

change was still significant because of the ability to more effectively conduct certain types of missions through collaboration of all assets.

10.2 Today's State

Practical applications of MUM teaming continue to evolve as confidence in unmanned vehicle reliability and functionality matures. Employment concepts are limited by data links, vehicle control interfaces, and level of autonomy. One recent example of practical application is when the USMC fielded a laser designation capability for Shadow as an enhancement/enabler of sensor-to-shooter operations for enemy/target of interest engagement in April 2010.

10.2.1 Unmanned Ground Vehicles (UGVs)

MUM teaming has steadily increased as technology has improved and users have found new and innovative methods to exploit this enhanced mission capability. Current missions include reconnaissance, surveillance, and target acquisition (RSTA); transport; countermining; explosive ordnance disposal; and the use of armed unmanned tactical wheeled vehicles for checkpoint security inspections. The integration of one-system remote video terminal (OSRVT) technology and distributed UGV control into ground combat vehicles is



leading to the adaptation of TTPs because all parties now receive the same picture at the same time, regardless of their location.⁶³ With over 4,000 OSRVT or like systems fielded between the Army, USMC, and USAF to date, it is clear that MUM teaming is becoming ever more pervasive in ground operations. These developments have also been the catalyst for the creation of the common robotic controller, a joint project between the Army and USMC to develop a universal, wearable controller to operate a wide variety of unmanned systems, including UGVs, UA, and unattended ground sensors. This effort is currently aimed at smaller platforms, but could be transitioned to include limited control (i.e., payload only) for larger platforms as the technology matures.

⁶³⁶³ Lt. Col. Adam Hinsdale, former Chief, UAS Division, Department of the Army Aviation Directorate, was quoted in October 2007: "Everyone, regardless of the platform, receives the same information at the same time, leading to true interoperability, the Army's key goal. The OSRVT is a vital component of manned/unmanned teaming, allowing all elements, air and ground, to view the same synchronized area of interest simultaneously for coordinated engagement, with either kinetic or nonkinetic effects." *UAS Video Terminal Connects Boots On The Ground To Eyes In The Sky*, by Kim Henry, Redstone Arsenal, AL, (AFNS), 9 October 2007.

10.2.2 Unmanned Aircraft Systems (UAS)

MUM teaming has been successfully demonstrated in combat operations to provide CCDRs with enduring surveillance of hostile activities in real/near-real time to accurately geolocate potential targets, to laser-designate targets, and to provide battle damage assessment. UAS have proven successful in performing their missions largely because they are able to remain visually and aurally undetected by hostile forces. They are providing the CCDR with critical tactical data, which are used to plan and support combat operations. When used in support of ground operations, UAS have proven invaluable in providing near-real-time intelligence to commanders engaged in combat and have directly contributed to successful mission completion. Armed UAS have the ability to engage targets directly or cooperatively with other air and ground systems. Additionally, LOI 3 (control and monitoring of the UA payload in addition to direct receipt of UA data) has been demonstrated successfully in combat operations with attack helicopter crews. The attack helicopter crew is able to see on their cockpit display the sensor outputs that give them overhead views to the target and surrounding area. This capability greatly enhances the attack helicopter crew's ability to identify, classify, and verify target locations to reduce the risk of fratricide. In September of 2010, the Army conducted an integration exercise featuring Apache helicopter pilots controlling Shadow, Hunter and Raven UAs.



The success of the exercise resulted in the inclusion of the LOI 2 and 3 UA control requirement into the AH-64, which gives the manned aircraft sensor and flight-path control and monitoring of the UA (less launch and recovery). The Apache Block III initial fielding is scheduled for 2012 and will incorporate LOI 2, 3, and 4 UA control. The AH-64 BLK III will have the capability to receive real-time UA FMV and the associated metadata (LOI 2), control the UA electro-optical/infrared (EO/IR) payload (LOI 3), and dynamically task the UA flight path (LOI 4), all from the front seat of the Apache. The initial combat operations in Afghanistan and Iraq validated the urgent need to integrate UAS capabilities with manned aircraft, specifically the attack platforms. Commanders recognized that they could dramatically reduce sensor-to-shooter times and improve situational awareness of helicopter pilots, while drastically reducing collateral damage and the potential for fratricide. They crafted an Operational Needs Statement for attack helicopter MUM teaming capability that led to a rapid prototype system for the Apache called Video from Unmanned Aircraft Systems for Interoperability Teaming – Level 2 (VUIT-2). The VUIT-2 system allows the AH-64 crew to receive video feeds from UA utilizing C-Band transmission. The Army has renamed this effort MUMT-2 and expanded it to UH-60 Black Hawk and OH-58D Kiowa Warriors.

Current MUM teaming applications are limited due to the fact the control interface currently requires a dedicated crew member to fly the UAS while another crew member flies the manned aircraft. However, some automated MUM mission segments are being developed. For example, the Navy and USAF have developed and demonstrated technology for MUM air refueling and have simulated cooperative MUM air combat missions.

10.2.3 Unmanned Maritime Systems (UMS)

MUM teaming is critical for the maritime environment. This is especially true for the undersea domain where physics prevent man from safely performing tasks to the same fidelity. There are many different aspects of MUM teaming for UMS that have been explored and implemented in various degrees: long-endurance undersea gliders send data ashore and receive human-initiated mission updates in near real-time; UUVs enable efficient port security, harbor defense, and mine clearance operations through change detection and autonomous investigation of mine-like objects; likewise, UUVs extend the footprint of manned hydrographic and bathymetric survey platforms to gather higher volumes of data while enabling people to focus on the tasks that require human oversight. Near-term enhancement, development and codification of Water Space Management/Prevention of Mutual Interference (WSM/PMI) doctrine and procedures will allow sophisticated collaboration between submarine or surface vessel operations and unmanned assets for mission accomplishment. Given the inherent challenges of the maritime environment, the future of MUM teaming will consist of multiple types of unmanned systems (UUV, USV, UAV, UGV) used collaboratively with manned platforms to collect, process, exploit, and disseminate data. An enduring and integrated net of undersea sensors partnered with USVs or UAVs for communication and controlled from a common command center will revolutionize how undersea missions are conducted by bringing transparency to an otherwise opaque battlespace. All maritime missions will benefit from reduced timelines and improved accuracy of information from which the combat commander can make engagement decisions.

10.3 Problem Statement

While strides have been made over the past decade to further enhance MUM teaming capabilities, several challenges persist that will continue to affect the amount of time it takes this technology to transition from the invention and adaptation phase to the acceptance phase. This timing will also directly affect the development of MUM teaming TTPs, which in turn will dictate the speed of MUM teaming from CONOPS into DoD doctrine.

Some of these challenges are technical. They range from near-term issues such as the limited ability to integrate and deconflict various radio frequencies across a secure communications network, to far-term issues such as the ability of one person to control multiple UASs and UGVs simultaneously while flying his or her primary aircraft. This ability requires a high degree of hardware and software interoperability, scalable autonomy, human system interfaces (HSIs), new collaborative control algorithms, and network mission tools. The platforms must do significant levels of onboard processing to not only reduce bandwidth required, but also collaborate with other unmanned vehicles without operator input. Other technical challenges result from the need to make tradeoffs between size, weight, and power limitations on the various platforms and the desire for increased performance and capability. One of the biggest potential challenges to MUM operations stems from the Services' desire to introduce swarms (large numbers



of micro-UAS operating semi-autonomously) into military operations with other manned and unmanned systems.

“Everyone, regardless of the platform, receives the same information at the same time, leading to true interoperability; this is the Army’s key goal.

- Lt. Col. Adam Hinsdale,
Chief, UAS Division,
Department of the Army Aviation Directorate

Other MUM missions have different challenges including cargo, air refueling, interdiction in contested areas, electronic/network attack (EA), suppression of enemy air defenses (SEAD), and other traditional air combat missions. The ability to communicate from a highly maneuverable aircraft to a highly maneuverable future UAS will require significant advances in autonomy and HSI. This advancement can be compounded if LPI communication is needed for missions such as EA, SEAD, or control of long-dwell insect-size vehicles collecting information inside buildings.

10.4 Way Ahead (2011–2036)

Some key events will affect the future of MUM teaming over the next 25 years. As improvements in communications and sensor technologies evolve, new tactics will surely follow. For instance, it should be expected that there will be a shift away from the current reliance on video with operators incorporating other sensors (such as audio or tactile) to augment the tactical picture. Also, as commanders continue to integrate multiple manned and unmanned systems into their operations, they will soon be able to implement a “field of view” approach, similar to the “God’s eye” perspective seen in many current video games. A commander will be able to view a target from multiple perspectives (i.e., UGV, UAS, or manned sensors), using multiple sensors, to obtain more robust and comprehensive situational awareness. As MUM advances, new HSI and autonomy will change the role of people in mission execution and dramatically increase their effectiveness.

The most significant advances in MUM operations will begin as Services migrate away from the current closed-loop scenario between sensor and shooter to networked systems. High endurance UAS already have mission teams geographically separated from the platform and from each other. Wide-area sensors are also changing the paradigm on STANAG 4586 LOIs and USIP development. Employing MUM segments as nodes on a larger network will change how missions are executed and will dramatically affect the combat effectiveness.

Investments in technologies such as automated air refueling, tactical data link control of maneuverable aircraft, and autonomy in the near term will enable “loyal wingman” operations. The effectiveness of air missions will not be achieved by a collection of assets, but collaboration between manned and unmanned systems within the context of a network. These nodes on the network will have scalable transparent control, not the brittle closed-loop control and inflexible autonomy algorithms used today.

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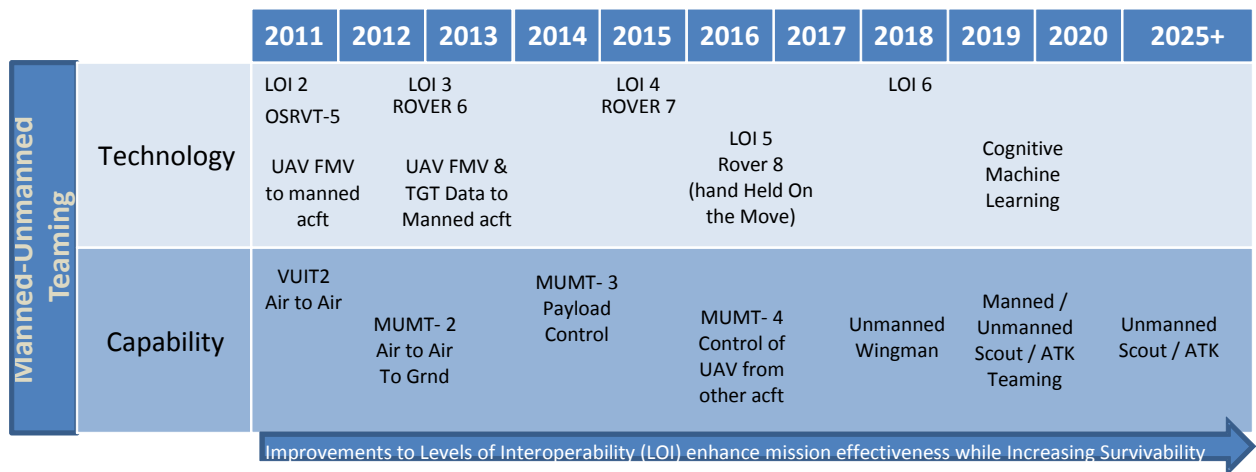


Figure 22. Manned Unmanned Teaming Roadmap.

The rapid growth in the OPTEMPO and demand for unmanned systems is a validation of their value to the CCDR. New concepts for the use of UAS, UGS, and UMS will result from experiences gained in combat. In the near future, it is likely that MUM teaming will be incorporated into an expanded set of operations.

11 SUMMARY

DoD has made great strides in developing, producing, and fielding unmanned systems. These systems have been effectively integrated across air, ground, and maritime domains to support a wide range of Joint warfighting needs. The inherent advantages of unmanned systems, including persistence and reduced risk to human life, have been clearly demonstrated in combat operations in Iraq and Afghanistan.

DoD envisions the continued expansion of unmanned systems in the future force structure. This expansion will include fielding additional systems in capability areas already supported by unmanned technologies, but also expanding into new mission areas not currently covered. As DoD defines a path toward this vision, a common set of challenges is apparent that cuts across all military Services, budgets, and all three domains of air, ground, and maritime. DoD, working together with industry, academia, and other Government agencies, will continue to map an affordable path forward to address these common challenges. Success in addressing the common issues discussed in this document and following the technology roadmaps summarized in Figure 23 (see next page) is critical to achieving the full potential offered by unmanned systems technologies.

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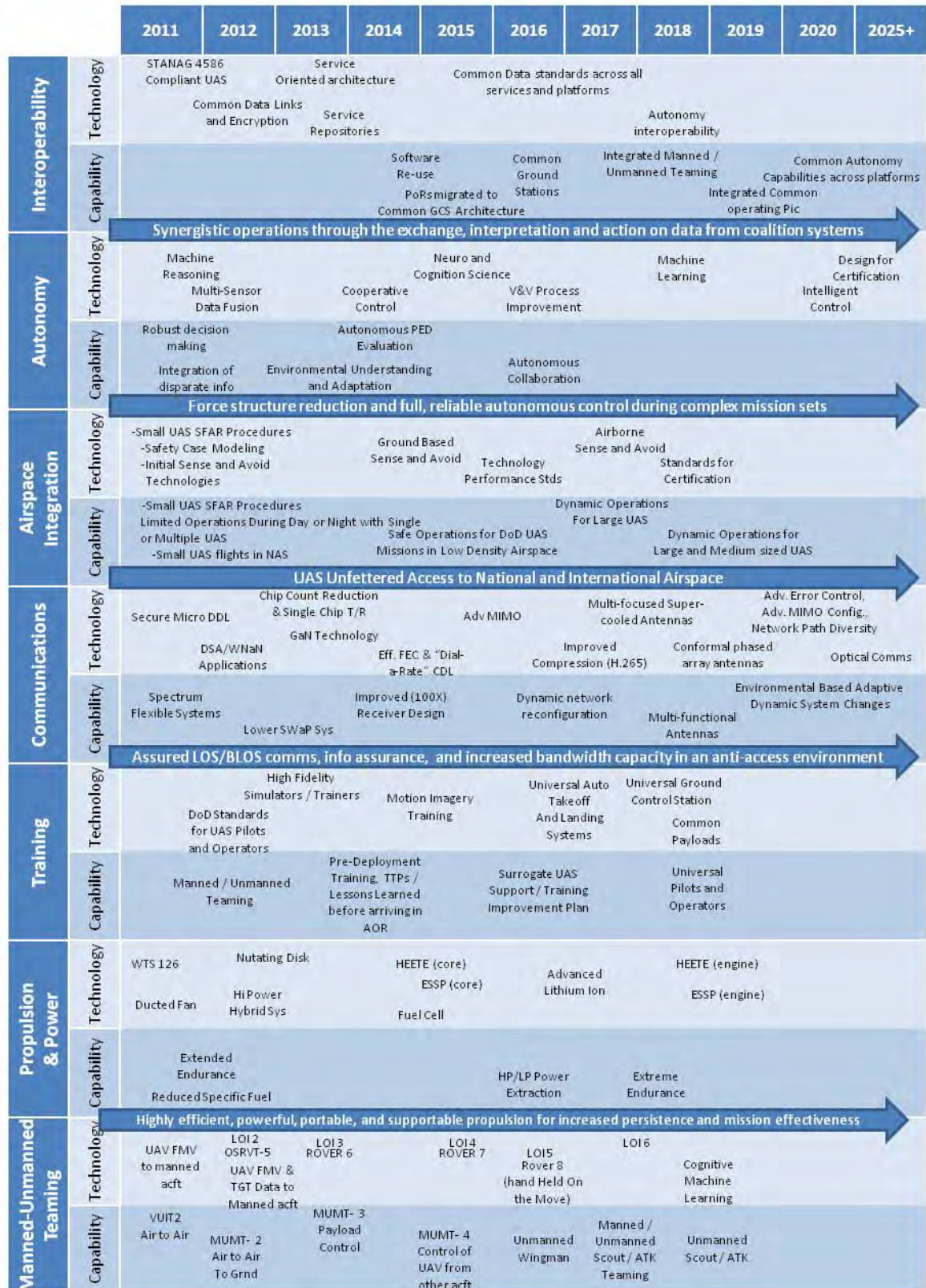


Figure 23. Summary of Technology Roadmaps.

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APPENDIX B: ABBREVIATIONS

4G	fourth generation
AAM	air-to-air missile
AATD	Army Aviation Applied Technology Directorate
ABSAA	airborne sense and avoid
ACAT	Acquisition Category
ACTD	Advanced Concept Technology Demonstration
ADC	analog-to-digital converter
AECV	All Environment Capable Variant
AEODRS	Advanced Explosive Ordnance Robotic System
AI	airspace integration
AMRDEC	Aviation and Missile Research, Development and Engineering Center
AMUST	airborne manned/unmanned systems technology
APU	auxiliary power unit
ASM	air-to-surface missile
ASW	anti-submarine warfare
ATS	air traffic services
AvGas	aviation gasoline
BA	Battlespace Awareness
BAMS	broad-area maritime surveillance
C2	command and control
CA	collision avoidance
CAP	Combat Air Patrol
CBP	Customs and Border Protection
CCDR	Combatant Commander
CDL	common data link
CFR	Code of Federal Regulations
CNO	Chief of Naval Operations
COA	Certificate of Waiver or Authorization
CONEMP	concept of employment
CONOPS	concept(s) of operations
COP	common operational picture
COTS	commercial, off-the-shelf
CSS	combat services support
CV	cargo variant
DDL	digital data link
DHS	Department of Homeland Security
DIMA	DARPA Interference Multiple Access
DLI	data link interface
DoD	Department of Defense
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel, and facilities
DOTMLPF-P	doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy
DPRK	Democratic People's Republic of Korea
DSA	dynamic spectrum access
DSPM	domain service portfolio management
EAU	electrical accumulator unit
EMI	electromagnetic interference
EMS	electromagnetic spectrum
ESSP	efficient small scale propulsion
EW	early warning
FA	Force Application
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FCS	Future combat system
FEC	forward error correction

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FMV	full-motion video
GaAs	gallium arsenide
GaN	gallium nitride
GBSAA	ground-based sense and avoid
GCS	ground control station
GCU	generator control unit
GDP	gross domestic product
gMAV	Gasoline-powered Micro Air Vehicle
GPS	global positioning system
GUI	graphical user interface
HAIPE	High Assurance IP Encryption
HEETE	highly efficient turbine engine
HSKT	Hunter Standoff Killer Team
ICAO	International Civil Aviation Organization
IED	improvised explosive device
I-IPT	Interoperability Integrated Product Team
IPSEC	Internet Protocol Security
ISR	intelligence, surveillance, and reconnaissance
ITU	International Telecommunication Union
JAUS	Joint Architecture for Unmanned Systems
JCA	Joint Capability Area
JCGUAV	Joint Capability Group Unmanned Aerial Vehicle
JMOC	Joint Maritime Operations Center
JSIDL	JAUS Service Interface Definition Language
JTRS	Joint Tactical Radio System
JTS	JAUS Tool Set
LCS	littoral combat ship
LOS	line of sight
LRU	line replaceable unit
MALE	medium-altitude, long-endurance
MDF	multisensor data fusion
MIMO	multiple-input, multiple-output
MISM	motion imagery systems matrix
MISP	motion imagery standards profile
MOA	Memorandum of Agreement
MPG	multiple power pod gas generator
MUM	manned-unmanned
NAS	National Airspace System
NII	national information infrastructure
NSA	National Security Agency
NSRDEC	Natick Soldier Research, Development & Engineering Center
NUWC	Naval Undersea Warfare Center
OA	open architecture
ODUSD(R)RTPP	Office of the Deputy Under Secretary of Defense (Readiness), Readiness and Training Policy and Programs
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OPTEMPO	operational tempo
OSD	Office of the Secretary of Defense
OSRVT	one-system remote video terminal
OUSD(AT&L)	Office of the Under Secretary of Defense, Acquisition, Technology and Logistics
PEO(LMW)	Program Executive Officer of Littoral and Mine Warfare
QRF	quick reaction force
RFI	request for information
ROV	remotely operated vehicle
RS-JPO	Robotic Systems Joint Project Office
RSTA	reconnaissance, surveillance, and target acquisition
S&T	science and technology

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SAA	sense and avoid
SAE	formerly known as the Society of Automotive Engineers, now known simply as SAE
SAR	synthetic aperture radar
SATCOM	satellite communications
SBIR	small business innovation research
SBU	sensitive but unclassified
SDO	standards development organization
SDS	spectrum-dependent system(s)
SF	special forces
SFC	specific fuel consumption
SIGINT	signals intelligence
SOA	service oriented architecture
SOCOM	Special Operations Command
SOFC	solid oxide fuel cell
SSPA	solid state power amplifier
SSPC	solid-state power controller
SSRA	spectrum supportability and risk assessment
STANAG	Standardization Agreement
STD-CDL	standard common data link
STUAS	small tactical unmanned aircraft system(s)
SuDDL	secure micro-digital datalink
SWaP-C	size, weight, power, and cooling
SWCC	special warfare combatant-craft crewman
TOC	total ownership costs
TPED	tasking, processing, exploitation, and distribution
TTP	tactics, techniques, and procedures
UA	unmanned aircraft
UAS	unmanned aircraft system(s)
UCAS	unmanned combat aircraft system
UGS	unmanned ground system(s)
UGV	unmanned ground vehicle
UMS	unmanned maritime system(s)
UMV	unmanned maritime vehicle
USC	United States Code
USIP	UAS System Interoperability Profiles
USV	unmanned surface vehicle
UUV	unmanned underwater vehicle
UW	unconventional warfare
VAATE	versatile affordable advanced turbine engine
VBSS	visit, board, search, and seizure
V&V	verification and validation
WSARA	Weapon Systems Acquisition Reform Act
WGS	Wideband Global SATCOM
WNaN	Wireless Network after Next
WRC	Worldwide Radio Communication Conference

APPENDIX C: GLOSSARY

Analysis and Production – The ability to integrate, evaluate, and interpret information from available sources and develop intelligence products that enable situational awareness.

Battlespace Awareness – The ability to understand dispositions and intentions as well as the characteristics and conditions of the operational environment that bear on national and military decision-making.

Building Partnerships – The ability to set the conditions for interaction with partner, competitor or adversary leaders, military forces, or relevant populations by developing and presenting information and conducting activities to affect their perceptions, will, behavior, and capabilities.

Collection – The ability to obtain required information to satisfy intelligence needs.

Command and Control – The ability to exercise authority and direction by a properly designated commander or decision maker over assigned and attached forces and resources in the accomplishment of the mission.

Communicate – The ability to develop and present information to domestic audiences to improve understanding; and, to develop and present information to foreign audiences to affect their perceptions, will, behavior and capabilities to further U.S. national security or shared global security interests.

Communicate Intent and Guidance – The ability to promulgate a concise expression of the operational purpose, assessment of acceptable operational risk, and guidance to achieve the desired end state.

Decide – The ability to select a course of action informed and influenced by the understanding of the environment or a given situation.

Deployment and Distribution – The ability to plan, coordinate, synchronize, and execute force movement and sustainment tasks in support of military operations. Deployment and distribution includes the ability to strategically and operationally move forces and sustainment to the point of need and operate the Joint Deployment and Distribution Enterprise. (JL(D) JIC pg 5 and pages 14-21)

Direct – The ability to employ resources to achieve an objective.

Engagement – The ability to use kinetic and non-kinetic means in all environments to generate the desired lethal and/or non-lethal effects from all domains and the information environment.

Force Application – The ability to integrate the use of maneuver and engagement in all environments to create the effects necessary to achieve mission objectives.

Health Readiness – The ability to enhance DoD and our Nation's security by providing health support for the full range of military operations and sustaining the health of all those entrusted to our care.

Information Transport – The ability to transport information and services via assured end-to-end connectivity across the NC environment.

Intelligence, Surveillance and Reconnaissance – The ability to conduct activities to meet the intelligence needs of national and military decision-makers.

Intelligence, Surveillance and Reconnaissance Dissemination – The ability to present information and intelligence products that enable understanding of the operational environment to military and national decision-makers.

Intelligence, Surveillance and Reconnaissance Planning and Direction – The ability to synchronize and integrate the activities of collection, processing, exploitation, analysis and dissemination resources to meet information requirements of national and military decision-makers.

Kinetic Means – The ability to create effects that rely on explosives or physical momentum (i.e., of, relating to, or produced by motion).

Logistics – The ability to project and sustain a logistically ready joint force through the deliberate sharing of national and multi-national resources to effectively support operations, extend operational reach and provide the joint force commander the freedom of action necessary to meet mission objectives.

Maneuver – The ability to move to a position of advantage in all environments in order to generate or enable the generation of effects in all domains and the information environment.

Maneuver to Engage (MTE) – The ability to move to a position of advantage in all environments in order to employ force.

Maneuver to Influence (MTInfl) – The ability to move to a position of advantage in all environments in order to affect the behavior, capabilities, will, or perceptions of partner, competitor, or adversary leaders, military forces, and relevant populations.

Maneuver to Insert (MTI) – The ability to place forces at a position of advantage in all environments.

Maneuver to Secure (MTS) – The ability to control or deny (destroy, remove, contaminate, or block with obstacles) significant areas, with or without force, in the operational area whose possession or control provides either side an operational advantage.

Mitigate – The ability to minimize the effects and manage the consequence of attacks (and designated emergencies on personnel and physical assets).

Monitor – The ability to adequately observe and assess events/effects of a decision.

Net-Centric – The ability to provide a framework for full human and technical connectivity and interoperability that allows all DoD users and mission partners to share the information they need, when they need it, in a form they can understand and act on with confidence, and protects information from those who should not have it.

Non-Kinetic Means – The ability to create effects that do not rely on explosives or physical momentum. (e.g., directed energy, computer viruses/hacking, chemical, and biological).

Prevent – The ability to neutralize an imminent attack or defeat attacks on personnel (combatant/non-combatant) and physical assets.

Processing / Exploitation – The ability to transform collected information into forms suitable for further analysis or action.

Protection – The ability to prevent/mitigate adverse effects of attacks on personnel (combatant/non-combatant) and physical assets of the United States, allies and friends.

Shape – The ability to conduct activities to affect the perceptions, will, behavior, and capabilities of partner, competitor, or adversary leaders, military forces, and relevant populations to further U.S. national security or shared global security interests.

Supply – The ability to identify and select supply sources, schedule deliveries, receive, verify, and transfer product and authorize supplier payments. It includes the ability to see and manage inventory levels, capital assets, business rules, supplier networks and agreements (to include import requirements) as well as assessment of supplier performance.

Understand – The ability to individually and collectively comprehend the implications of the character, nature, or subtleties of information about the environment and situation to aid decision-making.

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