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Outline:
§ DEWS Reference Architecture Development
§ Reference Architecture Implementation through MBSE tools
§ DEWS MOSA RA and SOSA harmonization

**15. SUBJECT TERMS**

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| **a. REPORT** | **b. ABSTRACT** | **c. THIS PAGE** | | | Susan Carpenito |
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# Directed Energy Weapons System Modular Open Systems Approach Reference Architecture (DEWS MOSA RA)

Keegan Merkert

June 2023

# Outline

- DEWS Reference Architecture Development
- Reference Architecture Implementation through MBSE tools
- DEWS MOSA RA and SOSA harmonization

This technical data deliverable was developed using contract funds under
Basic Contract No. W56KGU-18-D-0004.

# MOSA is …

**"An integrated business and technical strategy that employs a modular design and, where appropriate, defines key interfaces using widely supported, consensus-based standards that are published and maintained by a recognized industry standards organization."**

*"A Modular Open Systems Approach (MOSA) to Acquisition," Open Systems Joint Task Force (OSJTF)*

**Improve interoperability** – severable software and hardware modules that can be changed independently.

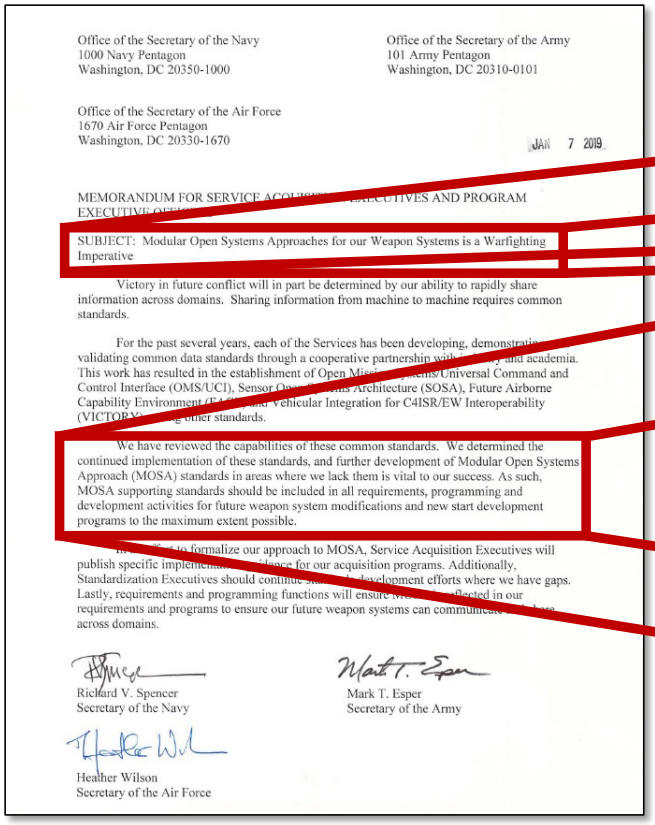
**Facilitate technology refresh** – delivery of new capabilities or replacement technology without requiring change to all elements in the entire system.

**Enhance competition** – open architecture with severable modules, allowing elements to be openly competed.

**Incorporate innovation** – operational flexibility to configure and reconfigure available assets to meet rapidly changing operational requirements.

**Enable cost savings/cost avoidance** – reuse of technology, modules, and/or elements from any supplier across the acquisition life cycle.

# Tri-Service Secretaries Memorandum: MOSA as a Warfighting Imperative (Jan 7, 2019)



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Washington, DC 20350-1000

Office of the Secretary of the Army
101 Army Pentagon
Washington, DC 20310-0101

Office of the Secretary of the Air Force
1670 Air Force Pentagon
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JAN 7 2019

MEMORANDUM FOR SERVICE ACQUISITION EXECUTIVES AND PROGRAM EXECUTIVE OFFICERS

SUBJECT: Modular Open Systems Approaches for our Weapon Systems is a Warfighting Imperative

Victory in future conflict will in part be determined by our ability to rapidly share information across domains. Sharing information from machine to machine requires common standards.

For the past several years, each of the Services has been developing, demonstrating, validating common data standards through a cooperative partnership with industry and academia. This work has resulted in the establishment of Open Mission Systems/Universal Command and Control Interface (OMS/UCI), Sensor Open Systems Architecture (SOSA), Future Airborne Capability Environment (FACE) and Vehicular Integration for C4ISR/EW Interoperability (VICTORY) among other standards.

We have reviewed the capabilities of these common standards. We determined the continued implementation of these standards, and further development of Modular Open Systems Approach (MOSA) standards in areas where we lack them is vital to our success. As such, MOSA supporting standards should be included in all requirements, programming and development activities for future weapon system modifications and new start development programs to the maximum extent possible.

To formalize our approach to MOSA, Service Acquisition Executives will publish specific implementation guidance for our acquisition programs. Additionally, Standardization Executives should continue standards development efforts where we have gaps. Lastly, requirements and programming functions will ensure MOSA is reflected in our requirements and programs to ensure our future weapon systems can communicate and share across domains.

Richard V. Spencer
Secretary of the Navy

Mark T. Esper
Secretary of the Army

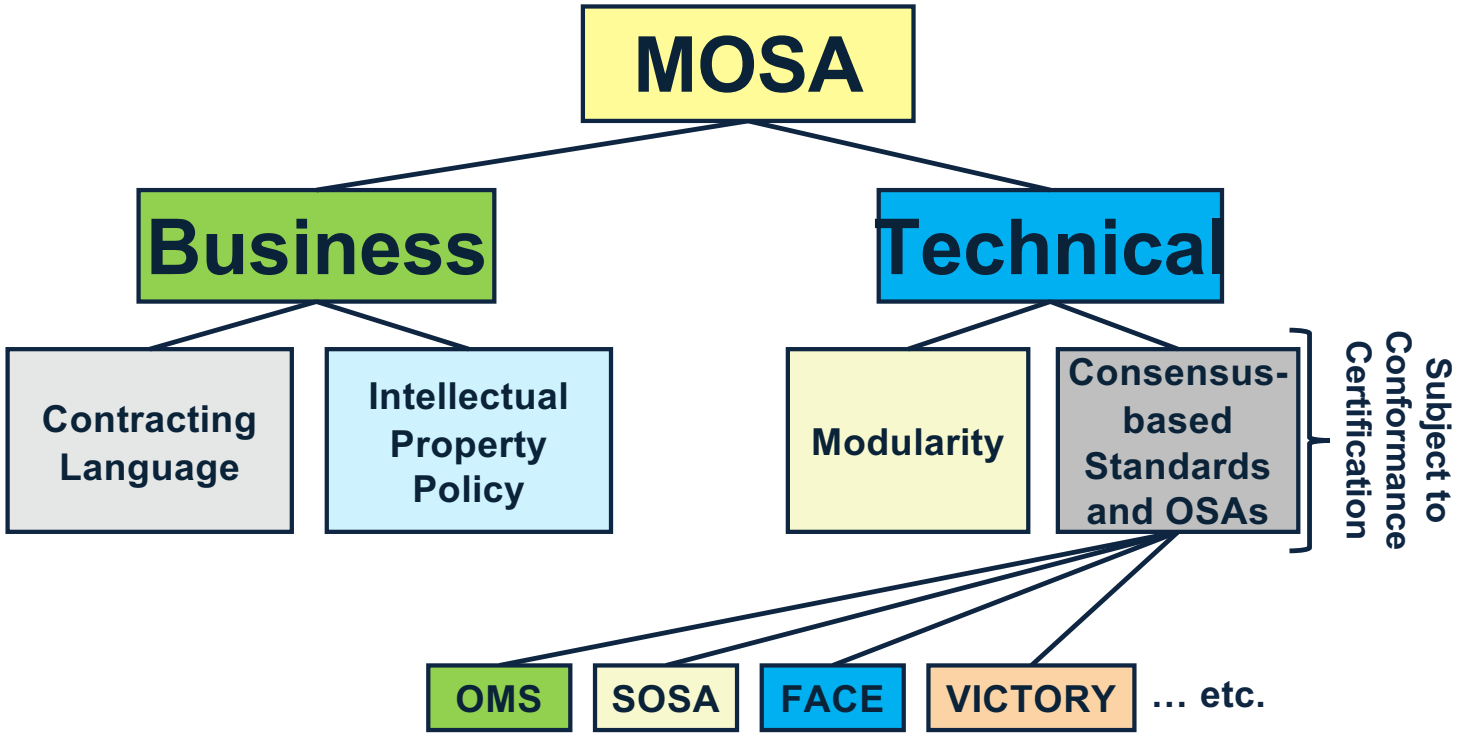
Heather Wilson
Secretary of the Air Force

SUBJECT: Modular Open Systems Approaches for our Weapon Systems is a Warfighting Imperative

We determined the continued implementation of these standards, and further development of Modular Open Systems Approach (MOSA) standards* in areas where we lack them is vital to our success. As such, MOSA supporting standards should be included in all requirements, programming and development activities for future weapon system modifications and new start development programs to the maximum extent possible.

* OMS/UCI, SOSA, FACE and VICTORY

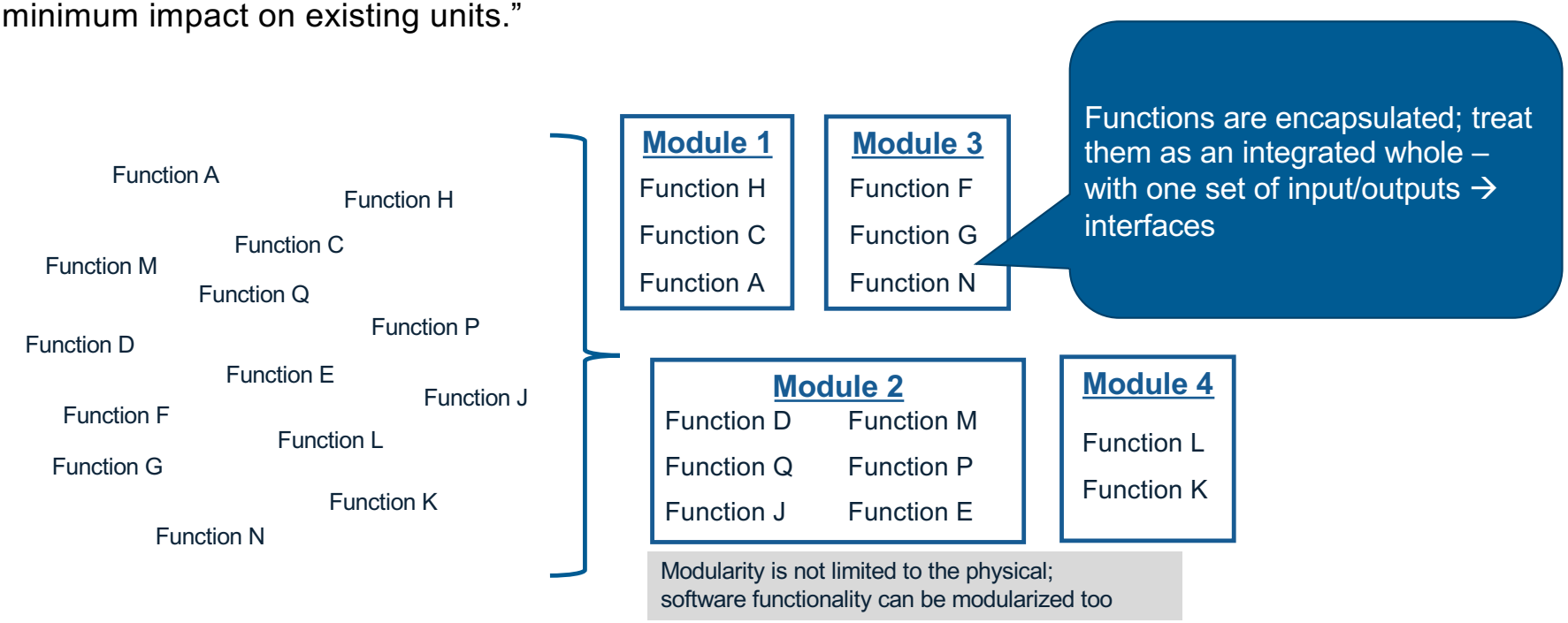
# Decomposing MOSA



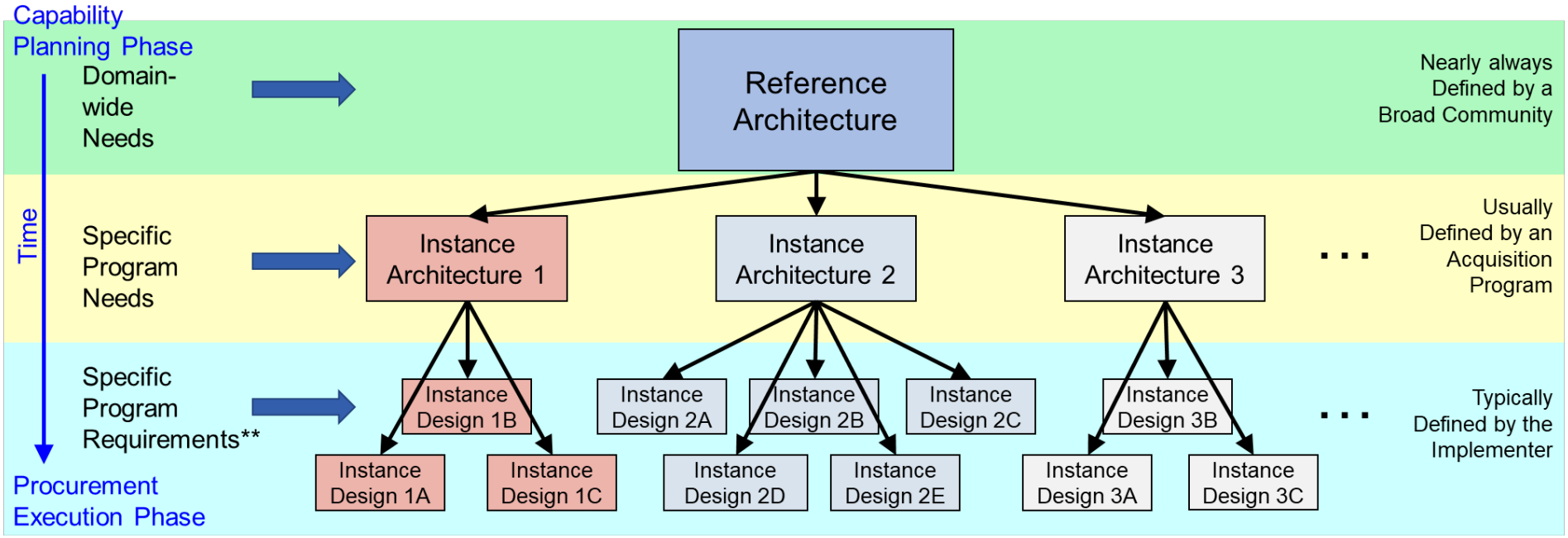

Derived from "SOSA 101"

# Defining Modularity for the DEWS MOSA RA

"… functionality is partitioned into discrete, cohesive, and self-contained units with well-defined interfaces that permit substitution of such units with similar components or products from alternate sources with minimum impact on existing units."



# How a Reference Architecture fits into the Development Process




* The Reference Architecture will evolve over time as experience from its use is folded back into it

** Selection of the Implemented Design will be based on factors such as price/performance trades, SWaP, etc.

Derived from SOSA 101

# Directed Energy Weapon System (DEWS) MOSA Reference Architecture

- Directed energy systems are becoming technically mature, on the verge of being more widely deployed
- Services and programs all going in their own direction – and there was no OSA for DEWS

## Needs

- MOSA-based approach to "guide and constrain" development and procurement
- Well-defined, government "owned" open interfaces between modules
- Developer-independent modules
- Service- and Host Platform-independent OSA

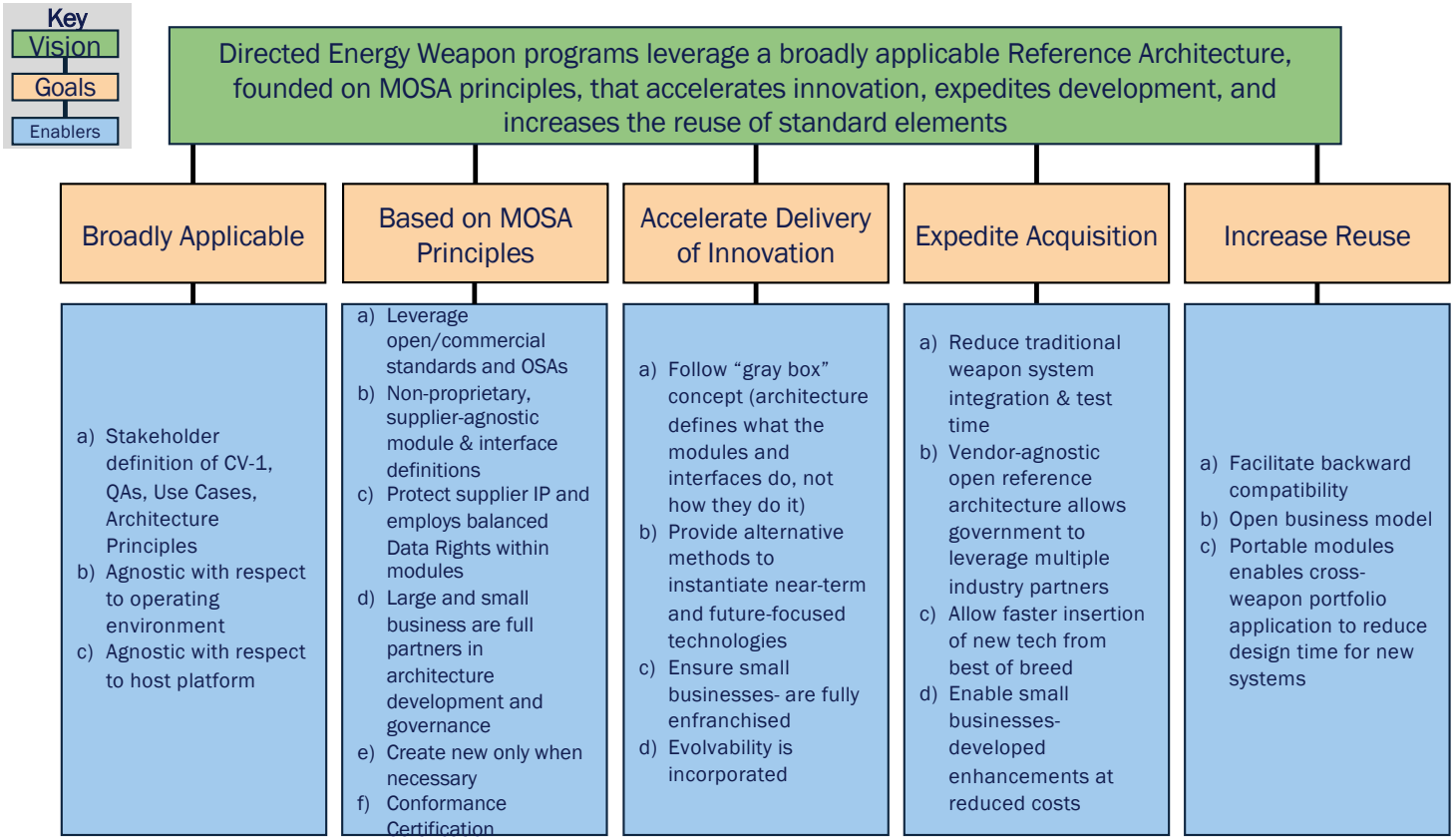
## To Enable

- Rapid, cost-effective, and supportable DEWS fielding (reduced time from R&D, to prototyping, to integration, to DT and OT)
- Extend service life of systems through incremental upgrades (including from third-party sources)
- Industrial base expansion and engagement → ecosystem (economies of scale)
- Aligned R&D investment
- Reuse across programs and Services

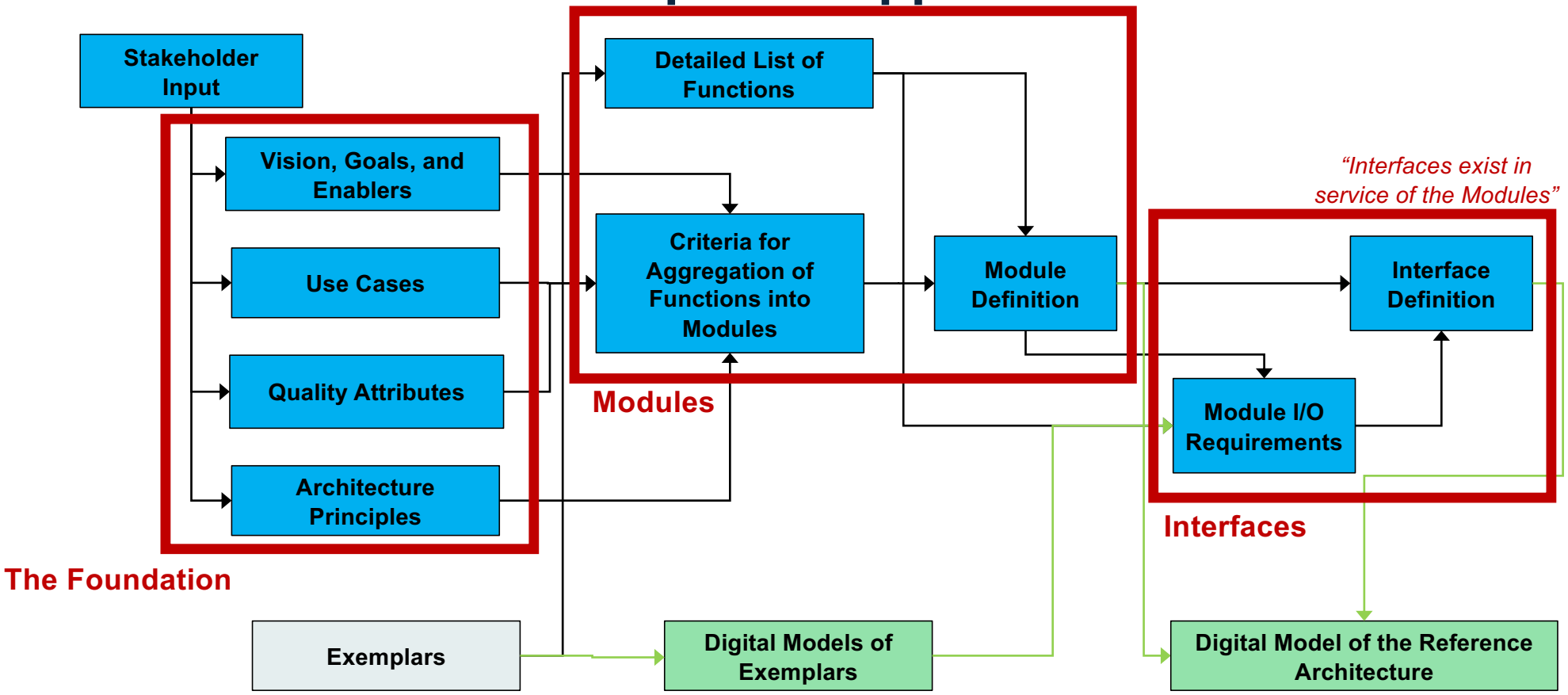
# Learn from Systems under Development

| Program Name | Service | Type | Domain | Government Lead | Industry Partners |
|---|---|---|---|---|---|
| Bane | Navy | HPM | Land | Dahlgren DEW Office (DEWO) | |
| Tactical High-Power Microwave Operational Responder (THOR) | USAF | HPM | Land | AFRL | BAE Systems (BAE), Leidos, Verus Research |
| DE-Maneuver Short Range Air Defense (MSHORAD) | Army | HEL | Land | Army RCCTO | Kord Technologies (Kord) |
| Indirect Fire Protection High Energy Laser (IFPC-HEL) | Army | HEL | Land | RCCTO, OSD, SMDC | Dynetics (a Leidos Co.), Lockheed Martin Corporation (LMC), MZA Associates Corporation (MZA) |
| High Power Joint Electromagnetic Non-Kinetic Strike (HiJENKS) | Navy: ONR USAF: AFRL | HPM | Air | Dahlgren /Kirtland | LMC |
| Self-protect High Energy Laser Demonstrator (SHiELD) | USAF | HEL | Air | AFRL | LMC |
| Airborne High Energy Laser (AHEL) | USAF | HEL | Air | AF Special Operations Command (AFSOC) | |
| High Energy Laser with Integrated Optical-dazzler and Surveillance (HELIOS) | Navy | HEL | Sea | PEO IWS 2 | LMC |
| Layered Laser Defense (LLD) | Navy | HEL | Sea | ONR | LMC |
| Solid State Laser Technology Maturation (SSL-TM) | Navy | HEL | Sea | Dahlgren | Northrop Grumman |

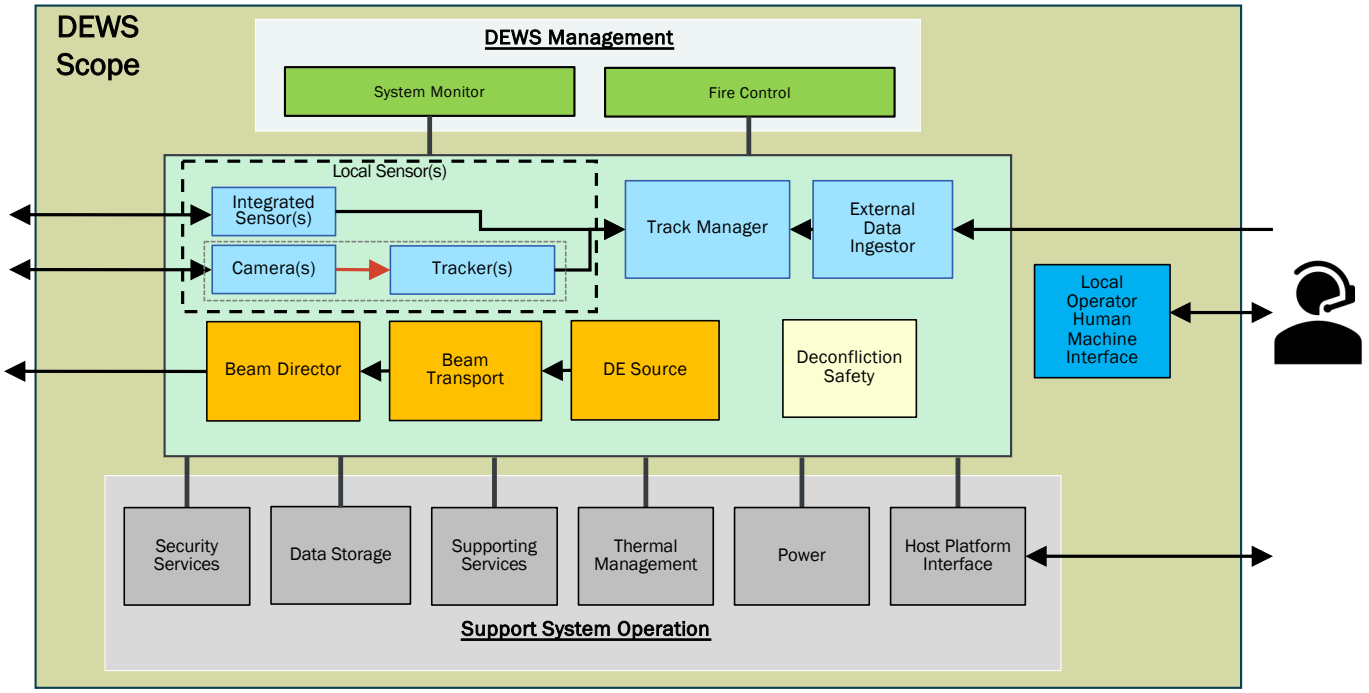
# DEWS RA Vision, Goals, Enablers



# DEWS MOSA RA Development Approach



# DEWS Open Reference Architecture Modules




* Showing only a small subset of interfaces to ensure clarity of the graphic

# Example of Functions Encapsulated in one Module

| ID | Name | Description |
|---|---|---|
| 21.11 | Display Situational Awareness Data | Displays map of system tracks relative to host platform. May include symbology (e.g., MIL-STD-2525), overlays, etc. Display sources include result of the current track store, Local Sensors, primary aperture, or direct feed from External Sensor or Host Platform. This display is also a user interface for functions such as designating tracks. If a track is to be designated for attack, the designated object is tagged as the target |
| 21.13 | Display Video | Displays Integrated Sensor video feeds to DEWS operator for use in carrying out engagements. The feeds may be real-time or pre-recorded. The operator display allows the replay, pause, rewind, fast forward, etc. (so-called TiVo functionality) permitting reconstruction and analysis. |
| 21.14 | H&S Status Update | Requests and receives system H&S from the System Monitor |
| 21.15 | Display and Control Status | Provides visual display of system status (received from Fire Control), view and control states/modes (conveyed to Fire Control),system power on/off, fault conditions and alarms (including the ability to drill-down to gather more detail, and clearing alarms) |
| 21.16 | Initiate BIT | Requests that the System Monitor Module that a Built-in Test (BIT) to be performed |

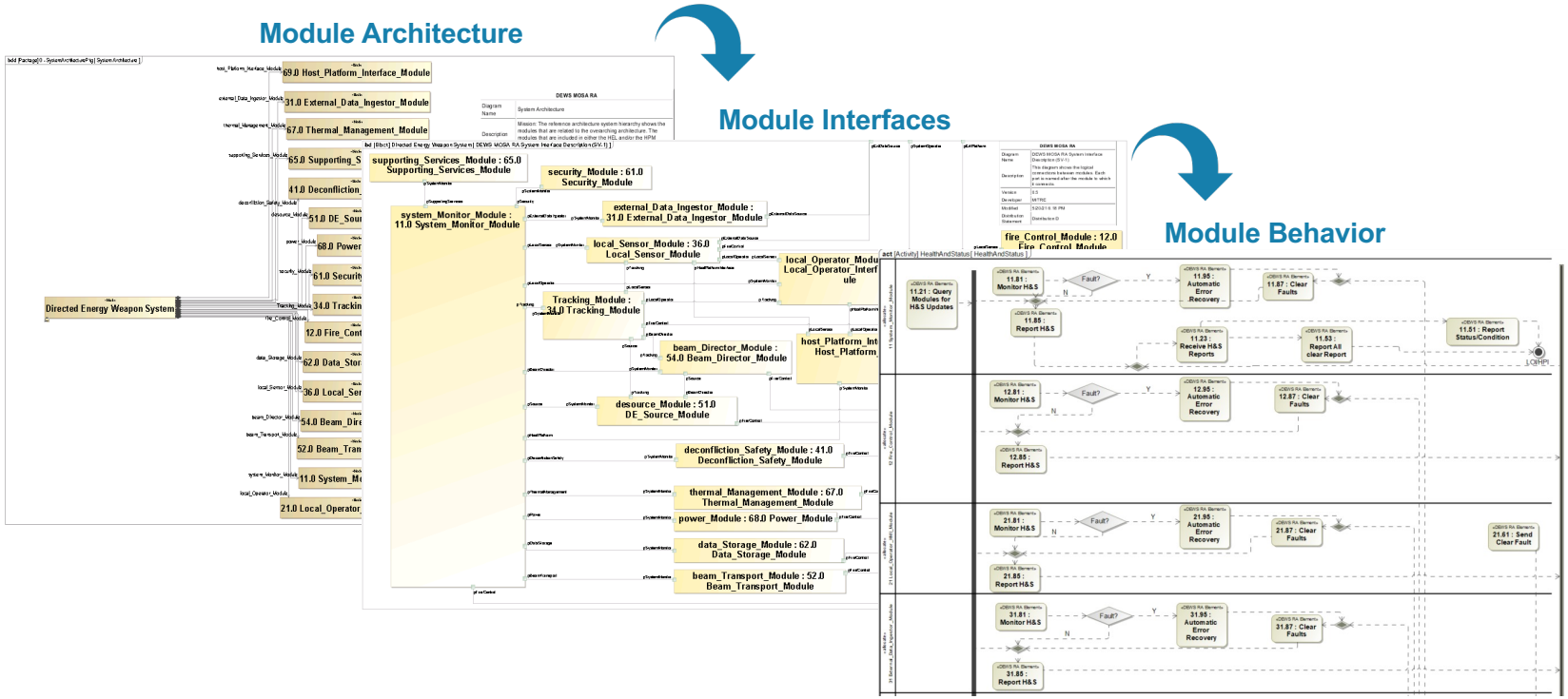
# Mapping Functions → I/O Needs → Inter-Module Interactions

| ID | Name | Input Needs | Input Source | Product Produced | Product Destination |
|---|---|---|---|---|---|
| 21.11 | Display Situational Awareness Data | Track Data (tracks and kinematic data) | Track Manager Module | Data in display format | Fire Control Module |
| 21.13 | Display Video | Video data | Local Sensor Module (real-time) and Data Storage Module (playback) | Video in display format | (local operator display) |
| 21.14 | H&S Status Update | H&S status report | System Monitor Module | Status request | System Monitor Module |
| 21.15 | Display and Control Status | System status data, | Fire Control Module | Data in display format, Control messages | (local operator display), Fire Control Module |
| 21.16 | Initiate BIT | Operator input | (controls internal to this module) | Request to initiate BIT | System Monitor Module |

Only showing five of the 26 functions for Module 21 (Local Operator HMI)

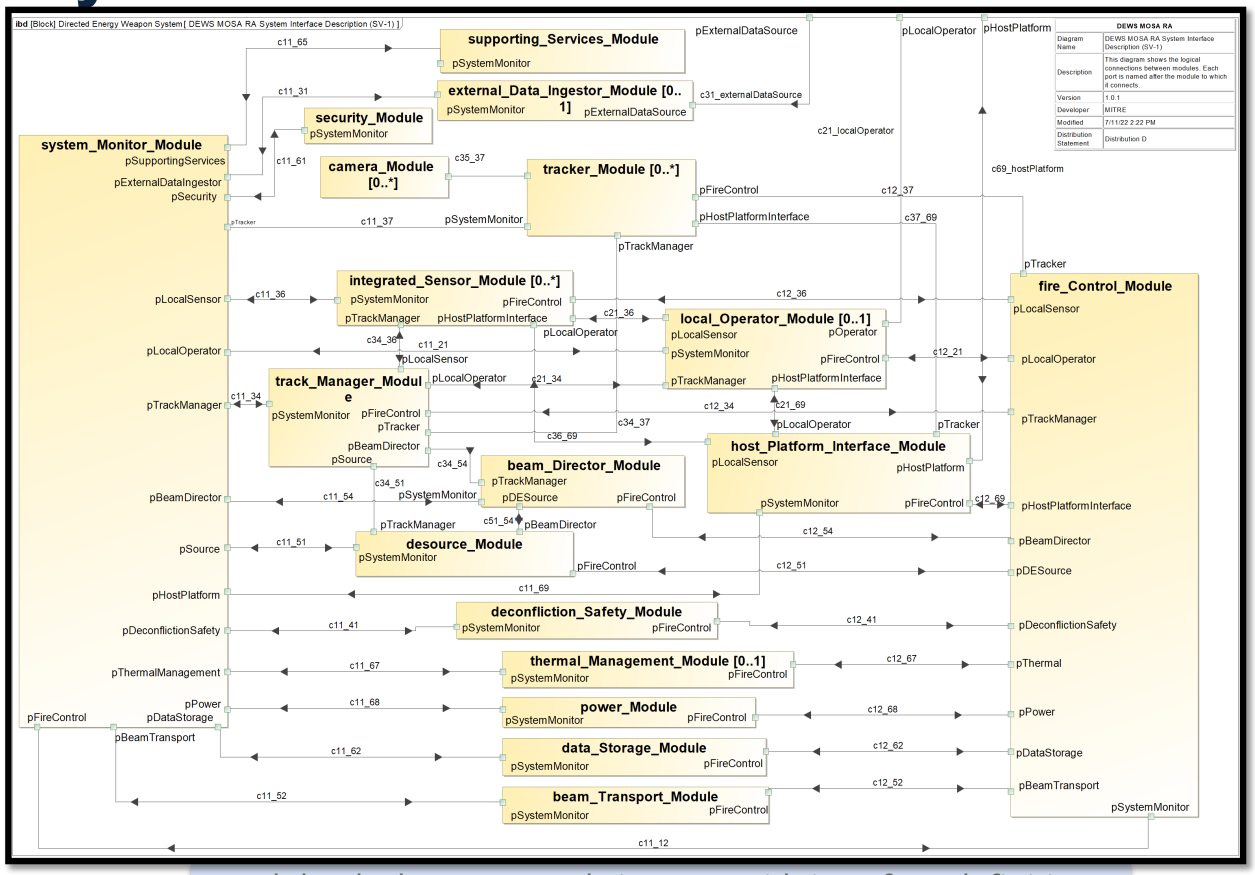
# DEWS MOSA Reference Architecture Model

- The DEWS MOSA RA will be provided as a Digital Engineering product, directly usable as a base for implementing programs
- Accompanying documentation will provide guidance on use, including with other standards



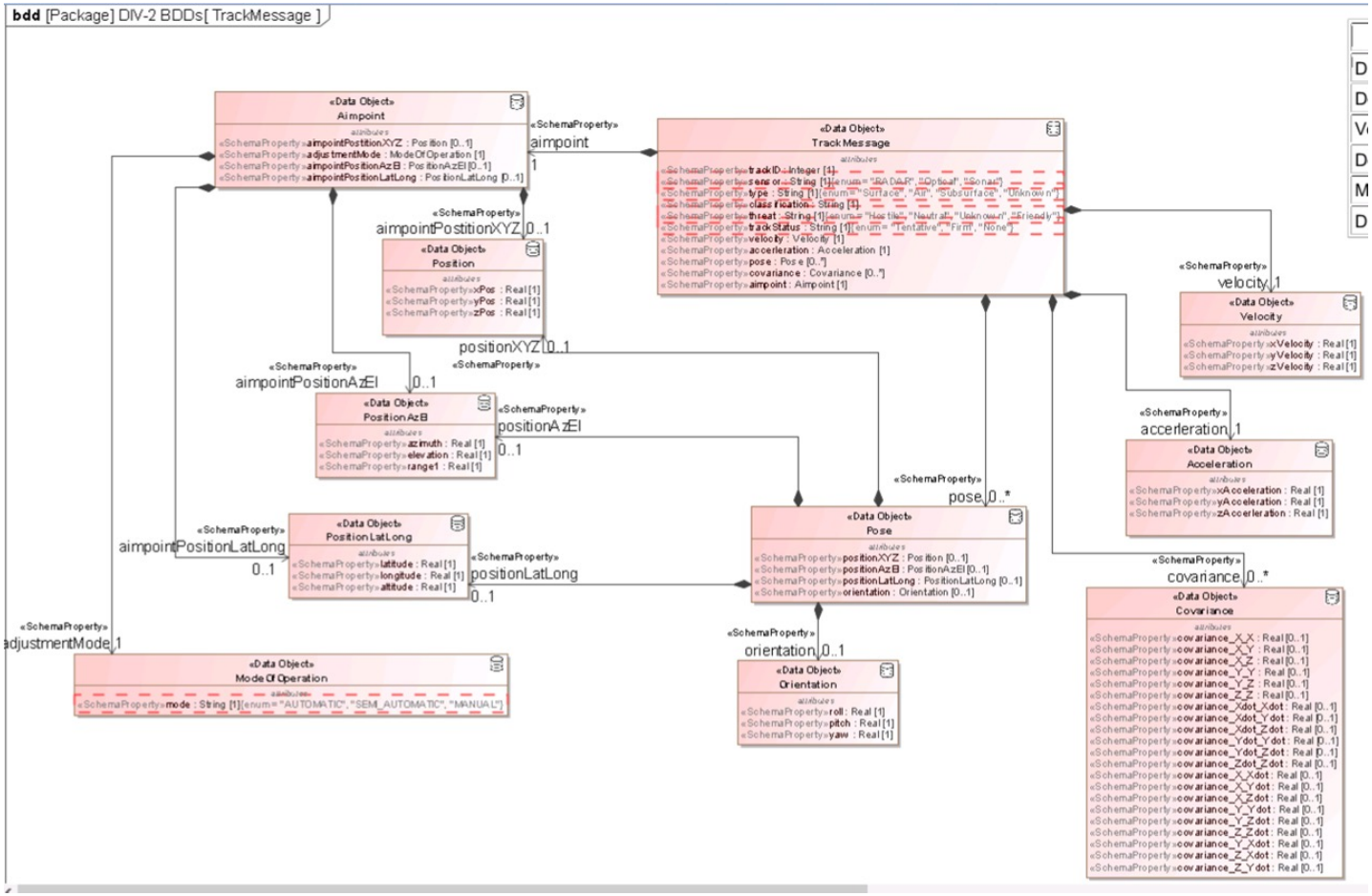
# DEWS RA Module System Architecture


Module Definitions




Module Blocks connected via ports with interface definitions

# DEWS RA Data Model – Track Message Data Object



# DEWS RA Data Model – Track Message Definitions

| API Object | Data Object Description | Name | Documentation | Type | Multiplicity | Minimum | Maximum | Enumeration |
|---|---|---|---|---|---|---|---|---|
| Acceleration | Three dimensional acceleration | xAcceleration | Acceleration of the x-component of an XYZ_ENU axis; if no reference point is specified, reference point should be the center of ownship/host; (units: Kilometers/Second^2) | Real | 1 | | | |
| Acceleration | Three dimensional acceleration | yAcceleration | Acceleration of the y-component of an XYZ_ENU axis; if no reference point is specified, reference point should be the center of ownship/host; (units: Kilometers/Second^2) | Real | 1 | | | |
| Acceleration | Three dimensional acceleration | zAccerleration | Acceleration of the z-component of an XYZ_ENU axis; if no reference point is specified, reference point should be the center of ownship/host; (units: Kilometers/Second^2) | Real | 1 | | | |
| Aimpoint | Aimpoint used by tracker | aimpointPostitionX | Three dimensional position of aimpoint | Position | 0..1 | | | |
| Aimpoint | Aimpoint used by tracker | adjustmentMode | Adjustment mode of the aimpoint | ModeOfOperation | 1 | | | |
| Aimpoint | Aimpoint used by tracker | aimpointPositionAz | Three dimensional position of aimpoint | PositionAzEl | 0..1 | | | |
| Aimpoint | Aimpoint used by tracker | aimpointPositionLatLong | Three dimensional position of aimpoint | PositionLatLong | 0..1 | | | |
| ModeOfOperation | Indicates the mode of an operation | mode | Indicates the mode of an operation | String | 1 | | | AUTOMATIC<br>SEMI_AUTOMATIC<br>MANUAL |
| Orientation | Three dimensional angular offset | yaw | Angular offset for pitch (units: Degrees). | Real | 1 | | | |
| Orientation | Three dimensional angular offset | pitch | Angular offset for pitch (units: Degrees). | Real | 1 | | | |
| Orientation | Three dimensional angular offset | roll | Angular offset for roll (units: Degrees). | Real | 1 | | | |
| Pose | Object position and orientation | orientation | How the object is placed or pointed | Orientation | 0..1 | | | |
| Pose | Object position and orientation | positionAzEl | Horizontal coordinate system position | PositionAzEl | 0..1 | | | |
| Pose | Object position and orientation | positionLatLong | Latitude and Longitude position | PositionLatLong | 0..1 | | | |
| Pose | Object position and orientation | positionXYZ | Three dimensional position | Position | 0..1 | | | |

Showing only a sample of the Track Message Definitions

# DEWS RA Activity Diagram (Power On Sequence)

Power Module: Receive Host Provided Power

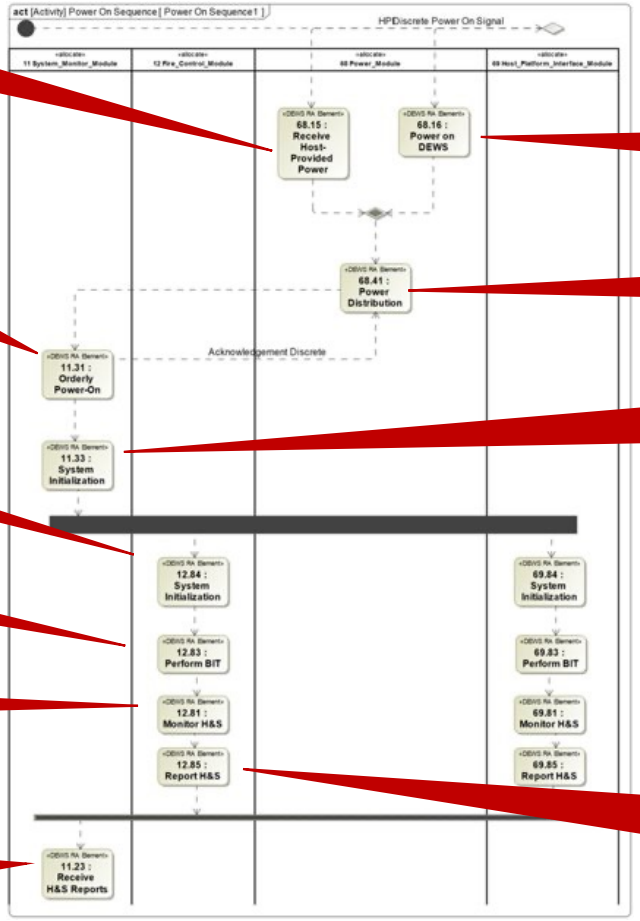
System Monitor Module: Orderly Power On

Fire Control Module: System Initialization

Fire Control Module: Perform BIT

Fire Control Module: Monitor H&S

System Monitor Module: Receive H&S Reports




Power Module: Power on DEWS

Power Module: Power Distribution

System Monitor Module: System Initialization

Fire Control Module: Report H&S

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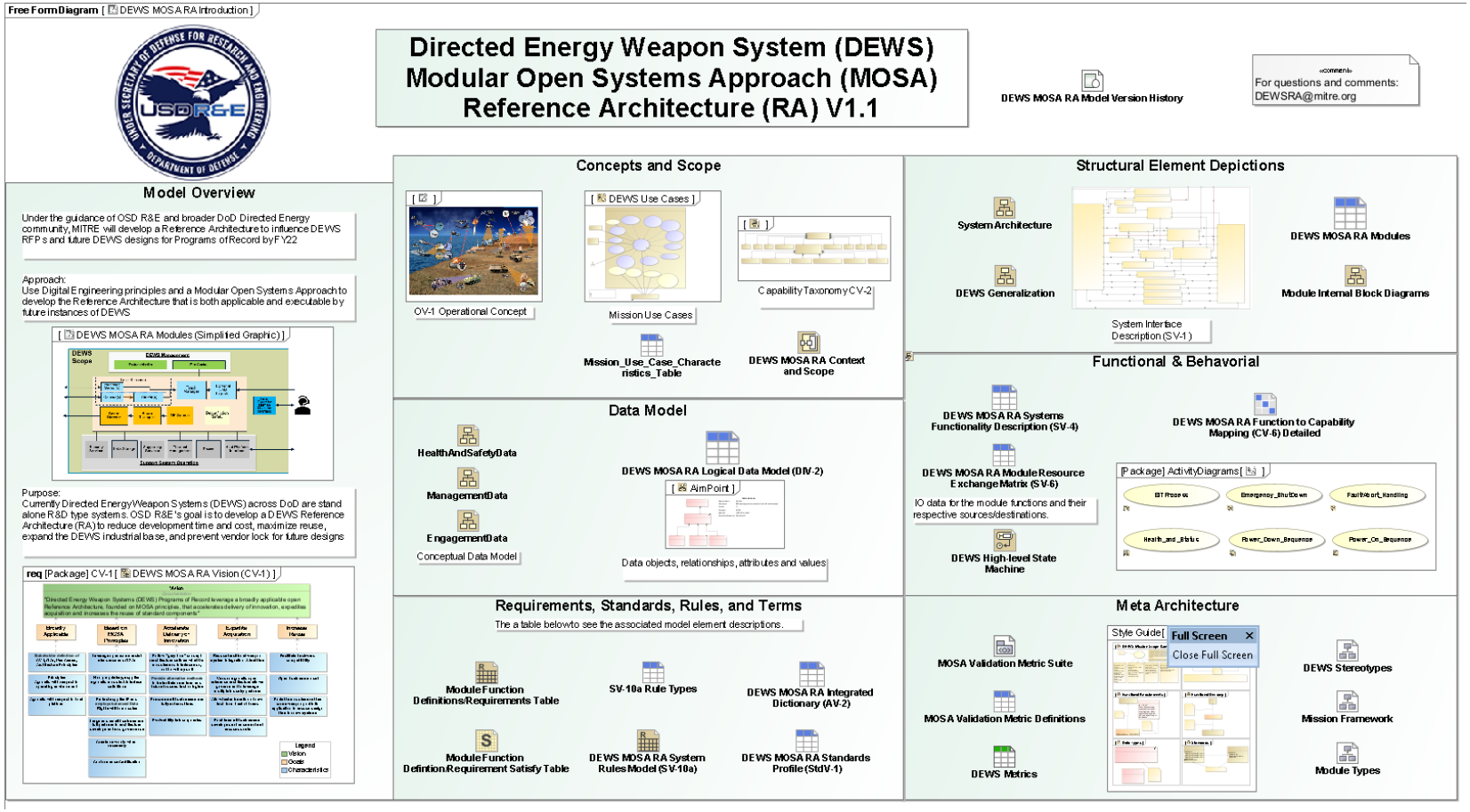
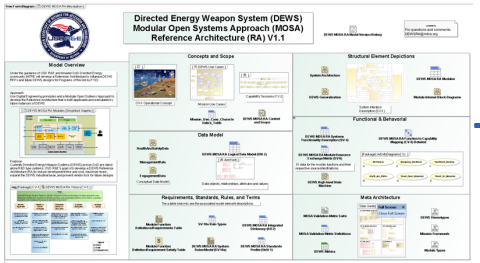
# DEWS RA Landing Page

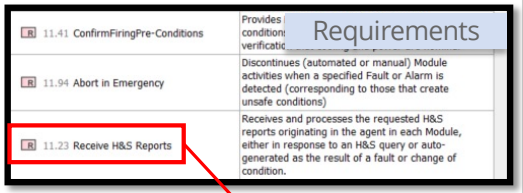


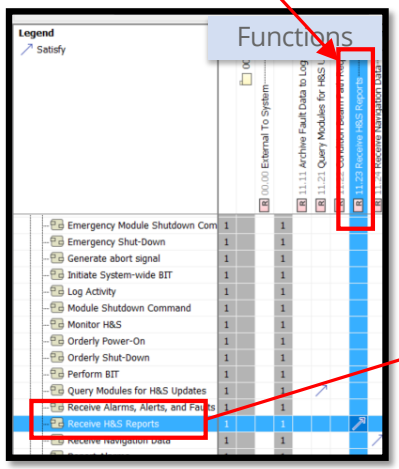
# DEWS RA Model Components



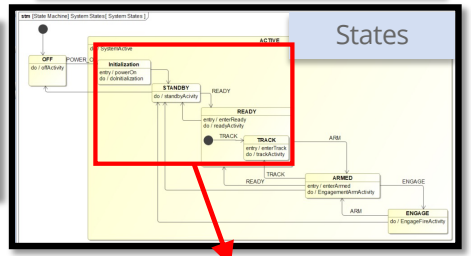

Landing Page to Navigate the Reference Architecture

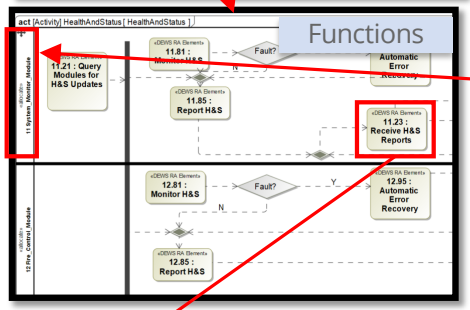
## Requirements

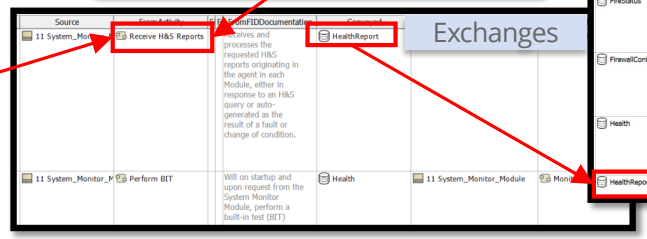


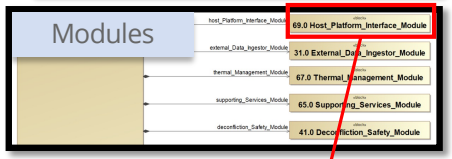

## Behavioral

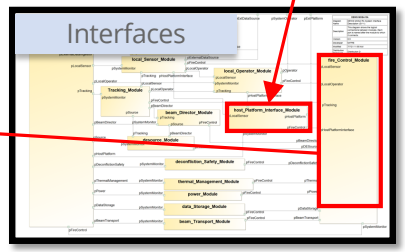


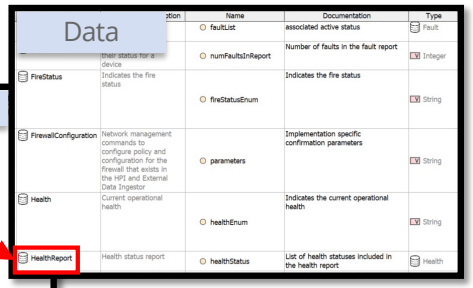




## Structural



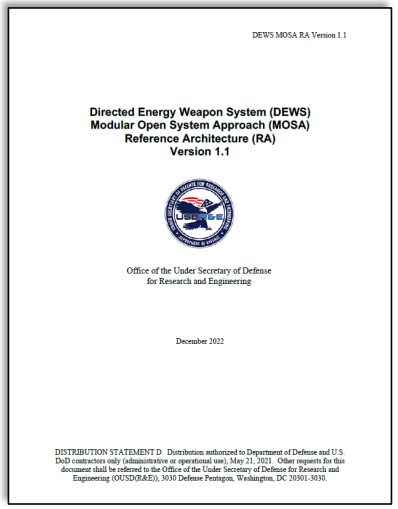
# Published version DEWS MOSA RA 1.1

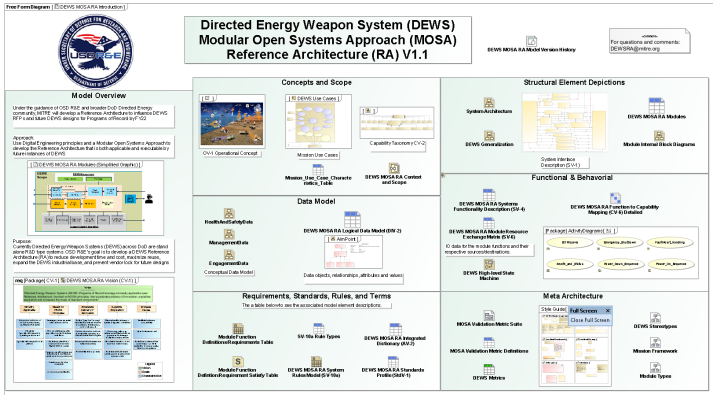
## Version 1.1 of the Reference Architecture

- Reference Architecture Document 1.1
- Magic Draw Digital Model

## Supplemental Material

- Implementation Guidance
- DEWS RA Assessment
- Acquisition Framework

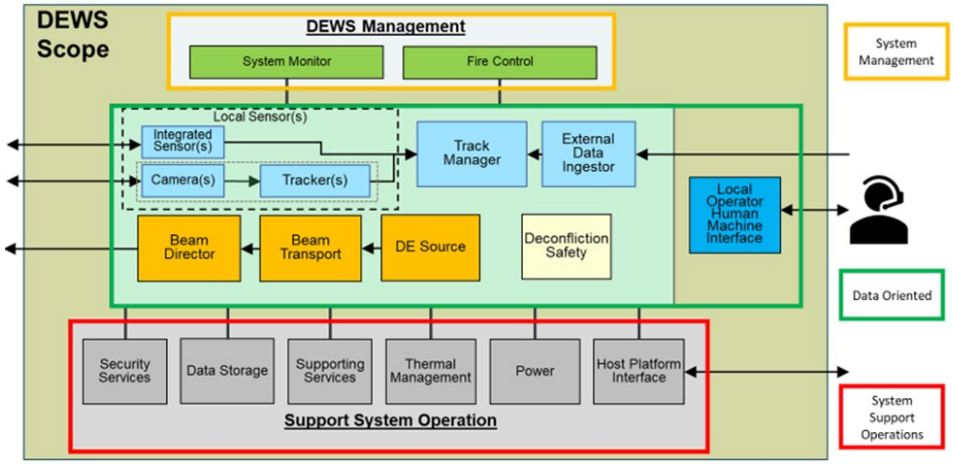


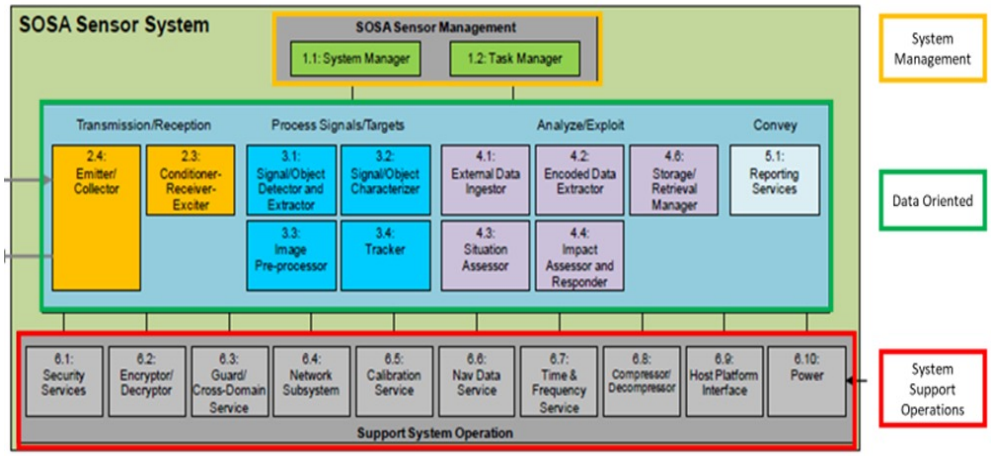




## Options to Access DEWS MOSA RA

| | |
|---|---|
| RA Document | The RA complete with imported tables, charts, graphics, and descriptions will be made available in an MS Word Report |
| HTML Extract | Export of MBSE model diagrams and data will be provided in HTML extract for users without access or familiarity with the Cameo software |
| Cameo zip file | Users will unzip all files to a folder and use Cameo to open the “DEWS_MOSA_Reference_Arch.mdzip” file. Cameo is a generic name for Dassault Systems CATIA Cameo Enterprise Architecture 19.0 SP4 also known as Magic System of Systems Architect (MSOSA) 19.0 SP4 |

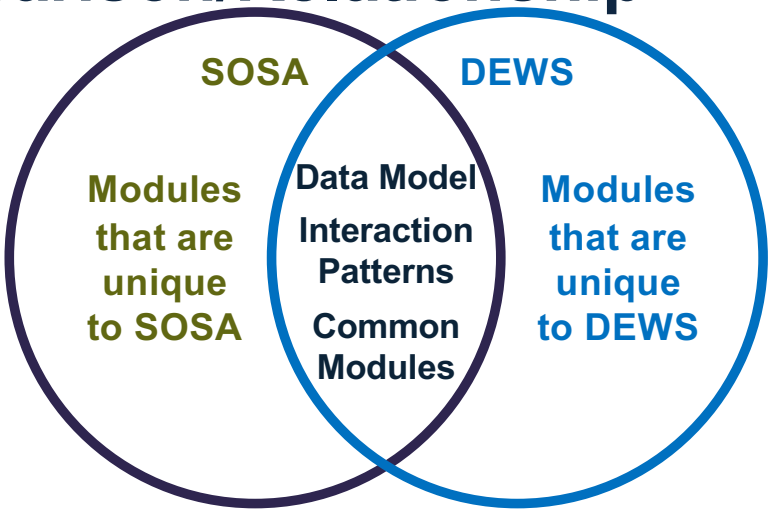
# DEWS MOSA RA integration with SOSA



# SOSA-DEWS Comparison/Relationship

Emitter / Collector
Conditioner-Receiver-Exciter
Signal/Object Detector and Extractor
Signal/Object Characterizer
Encoded Data Extractor
Situation Assessor
Impact Assessor and Responder
Reporting Services
Guard / Cross-Domain Service
Network Subsystem
Calibration Service
Compressor/Decompressor




Local Operator HMI
Local Sensor(s)
Deconfliction Safety
DE Source
Beam Transport
Beam Director
Thermal Management

System Manager / System Monitor
Task Manager / Fire Control
External Data Ingestor
Tracker / Track Manager
Security Services
Storage-Retrieval Manager / Data Storage
Nav Data and Time & Frequency Services / Supporting Services
Power
Host Platform Interface

MITRE

# SOSA-DEWS Comparison/Relationship

| DEWS_ID | DEWS Func | DEWS Description | SOSA Function |
|---|---|---|---|
| 68.13 | Generate Power | In cases where the DEWS operates independently of Host-provided power, generate its own power internally. This Function is optional | |
| 68.15 | Receive Host-Provided Power | In cases where the DEWS doesn't generate its own power, receive input electrical power (e.g., 440VAC, 120 VAC, etc.) from Host Platform Interface Module. This is an optional function. | **Convert between different power characteristics - From Host Platform Interface** |
| 68.16 | Power on DEWS | A discrete (an external button or key) to turn on the entire DEWS. After powering up, this function will request power distribution (68.41) to SMM to begin DEWS initialization | |
| 68.21 | Power conversion | Transform prime power to match requirements for each DEWS Module (including DC/AC conversion, high voltage, spike protection, etc.) | **Convert between different power characteristics** |
| 68.23 | Provide Storage of Electrical Power | Stores energy (for example, in a battery) for use when needed by system modules | **Store power for intermittent input power loss**<br><br>**Store power to provide long-term power to loads without input power** |

This element should be eliminated from DEWS as a functional requirement

Power-on process for DEWS is different from that of SOSA (which is very chassis-oriented)

Use of storage is different between DEWS (which is focused on energy surge) and SOSA (which is to coast through intermittent source outages)

Showing only a sample of the Power Module Functions

# SOSA-DEWS Comparison/Relationship

| DEWS_ID | DEWS Func | DEWS Description | SOSA Function |
|---|---|---|---|
| 68.41 | Power Distribution | Discharges energy as needed to support DEWS modules, based on system condition and individual module needs | **Distribute power from power supplies to power loads** |
| 68.55 | Power Conditioning | Delivers power at the proper voltage and current characteristics by protecting against high/low voltage or current conditions, filter noise, transient impulse suppression, etc. | **Condition/filter power** |
| 68.61 | Accept Remote Control | Provides a digital interface to Local Operator and/or Host Platform to enable remote management and control of all functions | **Provide a digital control interface** |
| | | | **Protect against voltage and over-current conditions** |
| | | | |

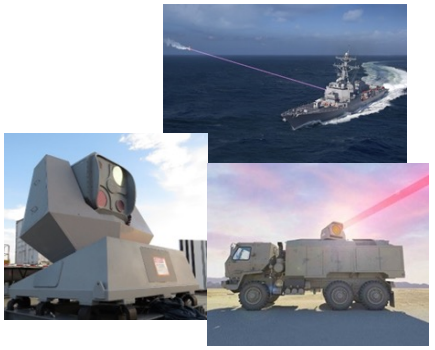
Consider adding this to Power Conditioning and remove as a separate function. Need clarification if this is internal to SOSA (protecting the sensor) or external (e.g., breaker on host to keep wiring from catching on fire)

Showing only a sample of the Power Module Functions

# Summary

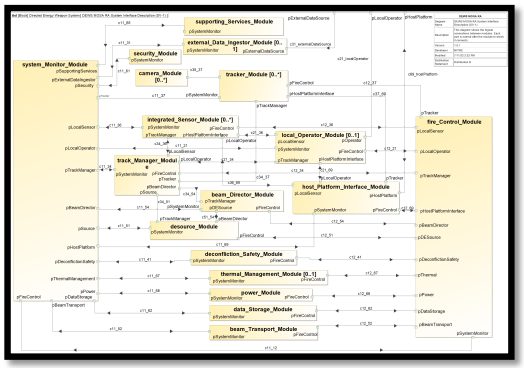
## Modular Open Systems Approach will accelerate development of Directed Energy Weapon Systems (DEWS)

- DEWS are becoming technically mature, but no OSA currently exists for these systems
- The DEWS MOSA RA will enable rapid, cost-effective, and supportable DEWS fielding



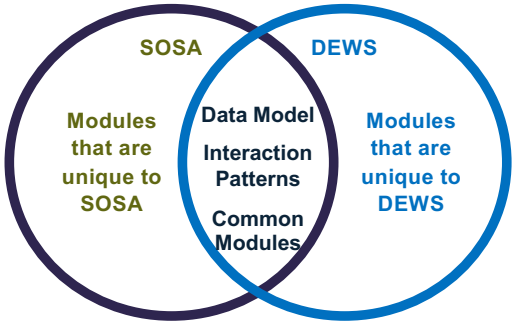
## Digital Engineering and model-based systems engineering (MBSE) provides an efficient means of standardizing a modular approach

- Digital products can be directly used by supporting programs
- Views can be adapted depending on a specific user's needs
- Technical updates are made in a single location in the digital model



## The DEWS MOSA RA is actively aligning modules with analogous SOSA module definitions

- Standardizes technical requirements under a common OSA



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# Backup

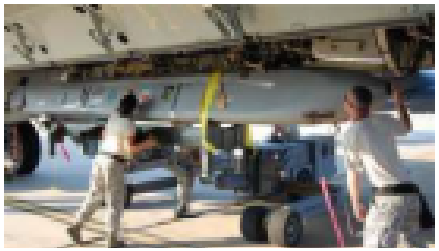
# Systems in Development

- Directed Energy Weapons (DEW) utilize beams of energy to destroy, damage, or disrupt a target. Examples include lasers, high power microwaves (HPM), and particle beams. They offer:
  - Potential to “Bend” the Cost Curve
  - Deep Magazines with Rapid Reload and Reduced Logistics
  - Highly reduced collateral damage
  - Precision Effects / Adjustable Effects
  - Engagement at the Speed of Light
  - Air / Land / Sea Platforms

DE-MSHORAD
Army
Laser

SSL-TM
Navy
Laser

THOR
Air Force/Army
HPM



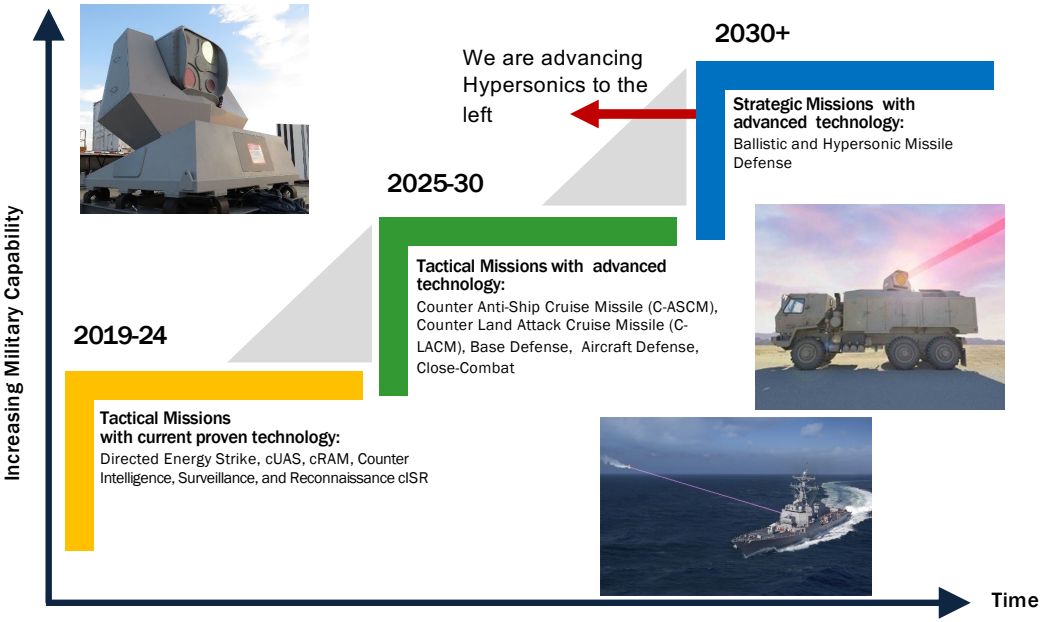
HiJENKS
Air Force/Navy
HPM

AHEL
SOCOM
Laser

# DEWS MOSA RA needs to grow along side of technology development

Key Aspects

- Achieve military dominance in every mission area where DEW makes technical sense
- Develop operational experience, knowledge, and confidence through operational demonstrations
- Advance and mature the technology to increase lethality, expand the mission set, and counter future adversaries
- Deliver new military capabilities with proven technology



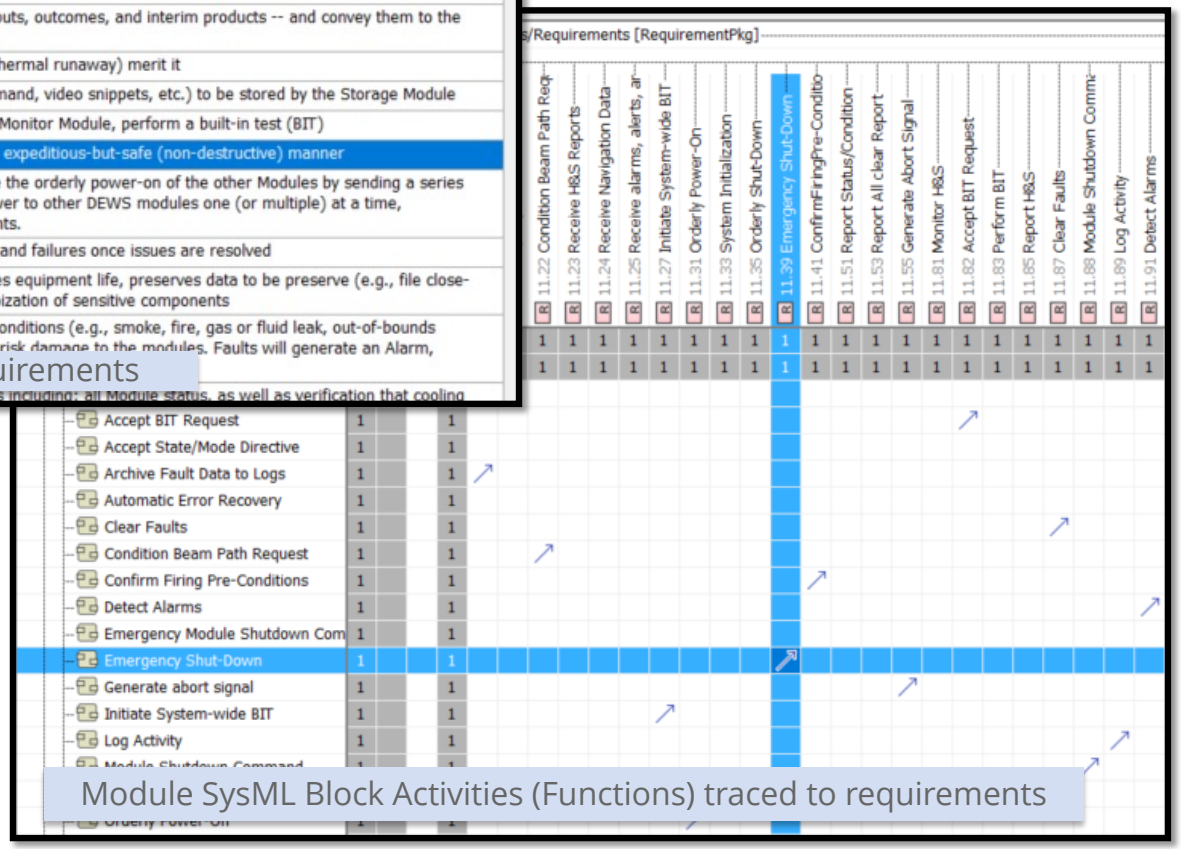
# DEWS Are Arriving and Being Used

- **ODIN – Optical Dazzling Interdictor, Navy**
  - Low-power laser system for dazzling of Unmanned Aerial System (UAS)-mounted Electro-Optical (EO)/Infrared (IR) sensors
  - First three systems installed on DDG51 Flt IIA ships, five more to be installed through 2023
- **HELIOS, Navy**
  - cUAS, cFIAC, 60 kW, Lockheed
  - To be installed on DDG51 Flt IIA ship in FY22
- **SSL-TM – Solid State Laser- Technology Maturation, Navy**
  - cUAS, cFIAC, 150 kW, Northrup
  - Installed on USS Portland (LPD 27) in 2019, deploys in 2021
- **CLAWS – Compact Laser Weapons System, Marines**
  - cUAS, 5 kW, Boeing, 5 systems, in CENTCOM
  - Integrated with Army C-RAM C2 system and radar
- **HELWS – High Energy Laser Weapons System, Air Force**
  - cUAS, 10 kW, Raytheon
  - 1 unit in CENTCOM
- **THOR – Tactical High Power Microwave Operational Responder, Air Force**
  - cUAS, Raytheon, OCONUS evaluation later this year
- **DE M-SHORAD** – Maneuvering Short Range Air Defense, Army
  - Experimental prototype with combat capability : 50 kW-Class laser for cUAS, cRAM, cRW
  - Prototype demo FY21, 1st Platoon (4 platforms) fielded FY22
- **IFPC-HEL – Fixed/Semi-Fixed Site Protection, Army**
  - Lab demo FY22: 300 kW-Class laser for cUAS, cRAM, cCM will inform prototyping effort
  - Joint range demonstration with Navy HELCAP in FY23, 1st Platoon (4 platforms) fielded FY24

# Functional and Interface Requirements

| | | |
|---|---|---|
| 459 | 11.97 Synchronize DEWS Module Time | Synchronizes Module time with Support Services time reference |
| 460 | 11.82 Accept BIT Request | Receives BIT request from System Monitor and notifies the Perform BIT Function to take action |
| 461 | 11.89 Log Activity | Generates a real-time log/record of significant outputs, outcomes, and interim products -- and convey them to the Data Storage Module |
| 462 | 11.55 Generate Abort Signal | Generates an Abort Signal when conditions (e.g., thermal runaway) merit it |
| 463 | 11.11 Archive Fault Data to Logs | Sends Fault Report (messaging, status, fault, command, video snippets, etc.) to be stored by the Storage Module |
| 464 | 11.83 Perform BIT | Will on startup and upon request from the System Monitor Module, perform a built-in test (BIT) |
| 465 | 11.39 Emergency Shut-Down | Executes a process that terminates operation in an expeditious-but-safe (non-destructive) manner |
| 466 | 11.31 Orderly Power-On | Receives power and is initialized, it will orchestrate the orderly power-on of the other Modules by sending a series of messages to the Power Module to distribute power to other DEWS modules one (or multiple) at a time, according to instance system power-on requirements. |
| 467 | 11.87 Clear Faults | Provides a method to recover from detected faults and failures once issues are resolved |
| 468 | 11.35 Orderly Shut-Down | Brings the system down in a manner that maximizes equipment life, preserves data to be preserve (e.g., file close-out), and requests (from the Security Module) zeroization of sensitive components |
| 469 | 11.91 Detect Alarms | Provides sensors to detect hazardous and unsafe conditions (e.g., smoke, fire, gas or fluid leak, out-of-bounds temperature or pressure, etc.), and failures which risk damage to the modules. Faults will generate an Alarm, |

Module functions are defined as requirements




Module SysML Block Activities (Functions) traced to requirements