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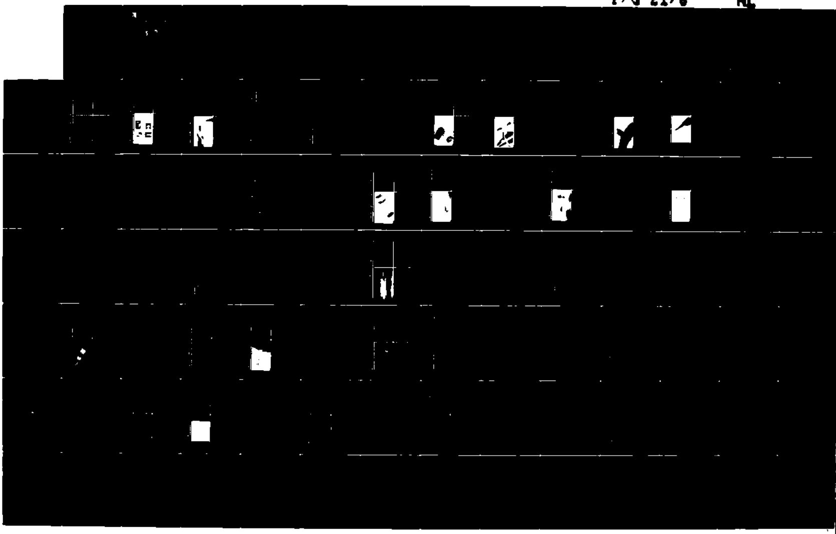

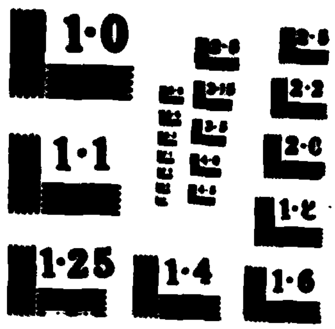
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December 1987

AFAL Technical Objective Document FY89

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Air Force Astronautics Laboratory

Air Force Space Technology Center
Space Division, Air Force Systems Command
Edwards Air Force Base,
California 93523-5000

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This report is a summary of technical objectives and approaches for research, exploratory development, and advanced development efforts being pursued, and to be pursued, at the Air Force Astronautics Laboratory between FY 88-92.

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22a. NAME OF RESPONSIBLE INDIVIDUAL: Wayne E. Roe

22b. TELEPHONE NUMBER (Include Area Code): (805) 275-5206

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INTRODUCTION

The Air Force Technical Objective Document (TOD) program is an integral part of the process by which the Air Force plans and formulates a detailed technology program to support the development and acquisition of Air Force weapons systems.

Each Air Force laboratory annually formulates its Science and Technology (S&T) program in response to available guidance based on USAF requirements, the identification of scientific and technological opportunities, and the needs of present and projected systems. These plans include proposed efforts to achieve desired capabilities, to resolve known technical problems, and to capitalize on new technical opportunities. The proposed efforts undergo a lengthy program formulation and review process. Generally, the criteria applied during the formulation and review are responsive to stated objectives and known requirements, scientific content and merit, program balance, developmental and life cycle costs, and consideration of payoff versus risk.

It is fully recognized that the development and accomplishment of the Air Force technical program are products of the teamwork on the part of the Air Force laboratories and the industrial and academic research and development community. The TOD program is designed to provide to industry and the academic community, necessary information on the Air Force laboratories' planned technology programs. Each laboratory's TOD is extracted from its S&T planning activity.

Specific objectives are:

a. To provide planning information for independent research and development programs.

b. To improve the quality of the unsolicited proposals and R&D procurements.

c. To encourage face-to-face discussions between non-Government scientists and engineers and their Air Force counterparts.

One or more TODs have been prepared by each Air Force laboratory that has responsibility for a portion of the Air Force S&T programs. Classified and limited distribution TODs are available from the Defense Technical Information Center (DTIC) and unclassified/unlimited TODs are available from the National Technical Information Service (NTIS).

The AFAL TOD contains a general overview of the Laboratory and its planned program. The appendix contains a program listing of our FY-88 and 89 expected new competitive contracted programs. These program listings are extracts from preliminary internal planning documents and should be viewed in that light. It is also important to remember that at the time this program list was prepared, it is like a "snapshot-in-time" and is subject to change.

HOW TO USE THIS DOCUMENT

Unsolicited proposals to conduct programs leading to the attainment of any of the objectives presented in this document may be submitted directly to an Air Force laboratory. However, before submitting a formal proposal, we encourage you to discuss your approach with the laboratory point of contact. After your discussion or correspondence with laboratory personnel, you will be better prepared to write your proposal.

As stated in the "AFSC Guide for Unsolicited Proposals" (copies of this informative guide on unsolicited proposals are available by sending $3.50 to Air Force Systems Command/DAPE, Andrews Air Force Base, Washington, DC 20334-5000), elaborate brochures or presentations are definitely not desired. The "ABCs" of successful proposals are accuracy, brevity, and clarity. It is extremely important that your letter be prepared to encourage its reading, to facilitate its understanding, and to impart an appreciation of the ideas you desire to convey. Specifically, your letter should include the following:

1. Name and address of your organization.

2. Type of organization (profit, non-profit).

3. Concise title and abstract of the proposed research and the statement indicating that the submission is an unsolicited proposal.

4. An outline and discussion of the purpose of the research, the method of attack upon the problem, and the nature of the expected results.

5. Name and research experience of the principal investigator.

6. A suggestion as to the proposed starting and completion dates.

7. An outline of the proposed budget, including information on equipment, facility, and personnel requirements.

8. Names of any other Federal agencies receiving the proposal (this is extremely important).

9. Brief description of your facilities, particularly those which would be used in your proposed research effort.

10. Brief outline of your previous work and experience in the field.

11. If available, you should include a description brochure and a financial statement.

As you read through the pages that follow, you may see a field of endeavor where your organization can contribute to the achievement of a specific technical goal. If such is the case, you are invited to discuss the objective further with the scientist or engineer identified with that objective. Further, you may have completely new ideas not considered in this document which, if brought to the attention of the proper organization, can make a significant contribution to our military technology. We will always maintain an open mind in evaluating any new concepts which, when successfully pursued, would improve our future operational capability.

On behalf of the United States Air Force, you are invited to study the objectives listed in this document and to discuss them with the responsible Air Force personnel. Your ideas and proposals, whether in response to the TODs or not, are most welcome.

The Air Force Astronautics Laboratory's technology program is organized into applications oriented major thrusts; one for each of the three major rocket propulsion applications areas, i.e., space systems, ballistic missiles, and air-launched missiles. Two other major thrusts make up the remainder of the Laboratory's program; one for technology which is (or will be) applied to several application areas, and one for, generally, non-propulsive space technologies which can best be described as Interdisciplinary Space Technology. The points of contact for these major thrust areas, should you desire additional information, are:

Space Systems Propulsion Technology Interdisciplinary Space Technology	Mr Melvin Rogers AFAL/XRX Autovon 525-5344 Commercial (805) 275-5344
Ballistic Missile Propulsion Technology	Dr Daweel George AFAL/XRX Autovon 525-5342 Commercial (805) 275-5342
Air-Launched Missile Propulsion Technology	Mr Robert Biggers AFAL/XRX Autovon 525-5341 Commercial (805) 275-5341
Multiple Applications Propulsion Technology	Mr Wayne Roe AFAL/XRX Autovon 525-5206 Commercial (805) 275-5206
Strategic Defense Initiative Propulsion Technology	Col Thomas W. Redmond AFAL/CR Autovon 525-5324 Commercial (805) 275-5324

LABORATORY MISSION

The Air Force Astronautics Laboratory (AFAL) is the principal AFSC organization charged with planning and executing USAF research, exploratory and advanced development programs for interdisciplinary space technology and rocket propulsion. Space technology includes spacecraft technology, launch vehicle technology, launch and in-space operations, and logistics technology. Rocket propulsion includes propellants, combustion, plume phenomenology, rocket propulsion materials and structures, solid propellant, rocket motors, liquid propellant rocket feed systems and engines, electric propulsion, hazard assessment, and rocket test techniques and instrumentation. There are two parts to the AFAL mission - first to develop new technology for the Air Force missiles and space systems of the future; and second to provide technical support to other organizations within the Air Force, particularly the Systems Program Offices (SPOs) that produce the end items. This mission is graphically depicted in Figure 1.

The technology advancement programs cover the complete spectrum of detailed basic research (6.1), exploratory development (6.2) and advanced development (6.3). The Laboratory is responsible for maintaining a superior technical base in all types of rocket propulsion and interdisciplinary space-related disciplines which will provide options for the development of future high performance Air Force systems and to prevent technological surprise. The technical management assistance includes engineering and scientific consultation, technical direction of programs, managing contractual efforts and executing in-house analytical and experimental programs.

INVESTMENT STRATEGY

The Laboratory strives to have a balanced investment strategy that takes into account (1) Air Force needs as stated by the system users, (2) Air Force mission capability deficiencies as identified in documents such as Vanguard Planning Summary, Military Space Systems Technology Plan (MSSTP), and the Logistics Long Range Planning Guide, (3) AFSC Forecast II, and (4) basic technological advances, otherwise known as "Technology Push." We use an in-house management council, made up of the Commander and eight senior Laboratory members, to make the decisions on where we will make an investment. Decisions are made within the limitations of the Laboratory's budget, manpower and facilities. Our planning process is shown in Figure 2. We take into account the "Big Picture" at the start of the process, assessing the Air Force needs for each of our major thrust areas. Resource allocations are issued for each of our technology clusters. We go through a process of internal competition at the cluster level evaluating ideas for new programs and also evaluating the on-going cluster levels of investment. We always demand of ourselves whether we have a valid rationale that answers, "What's in it for the Air Force?" We consider whether the program is answering a valid Air Force requirement or whether it is a fundamental effort that will exploit technology to achieve increased or new capabilities, such as efforts highlighted by Forecast II, etc. We realize that there are times when we should strive to extend technological boundaries, and we do invest in these areas, but we also don't do technology for technology's sake - we do it for the Air Force's sake. We do it because we believe that with this new technology it will find application in Air Force Systems of the future and, therefore, it is a good investment.

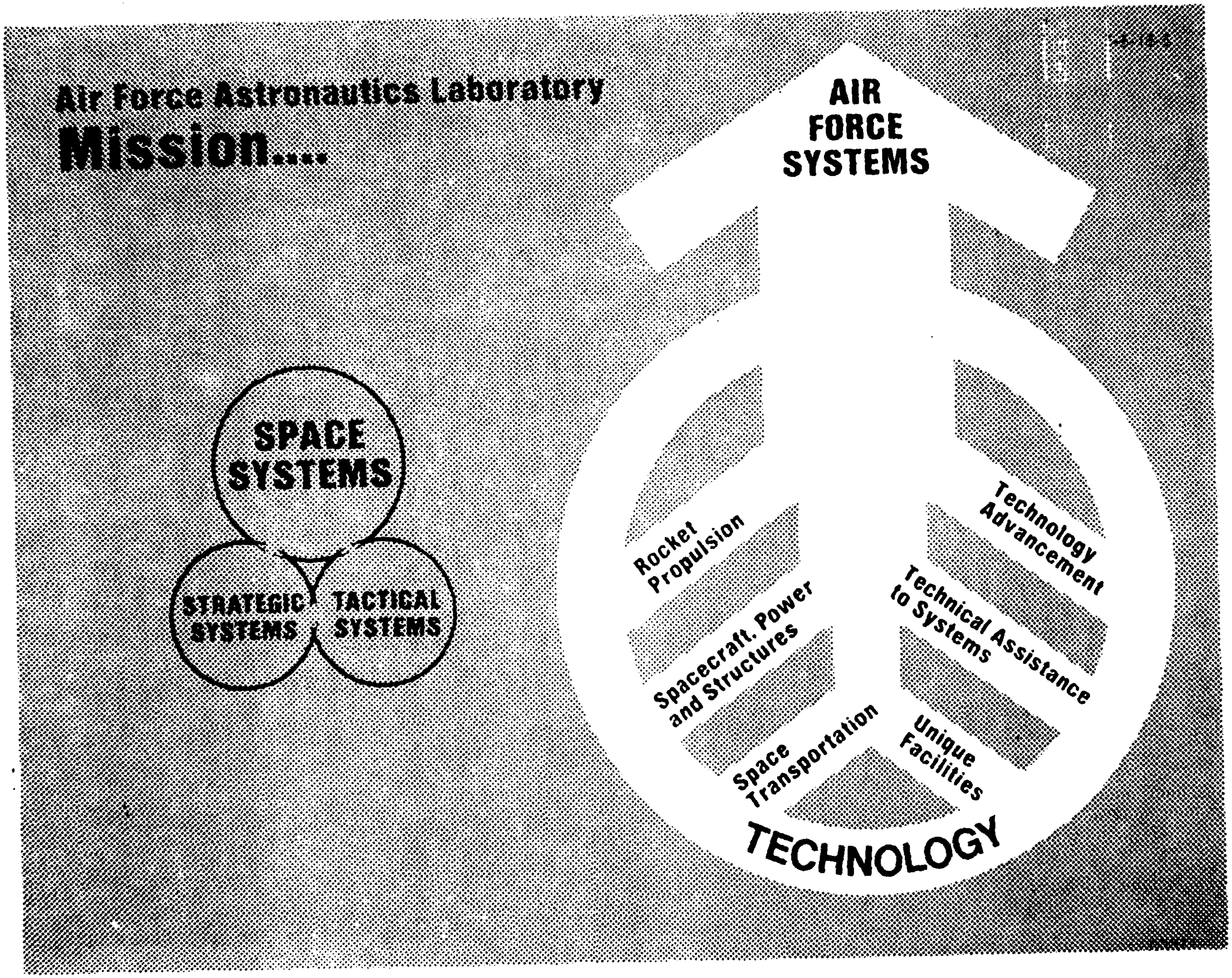

Air Force Astronautics Laboratory
Mission....
SPACE SYSTEMS
STRATEGIC SYSTEMS
TACTICAL SYSTEMS
AIR FORCE SYSTEMS
Rocket Propulsion
Spacecraft, Power and Structures
Space Transportation
Unique Facilities
Technical Assistance to Systems
Technology Advancement
TECHNOLOGY

FIGURE 1

AFRPL PLANNING PROCESS....

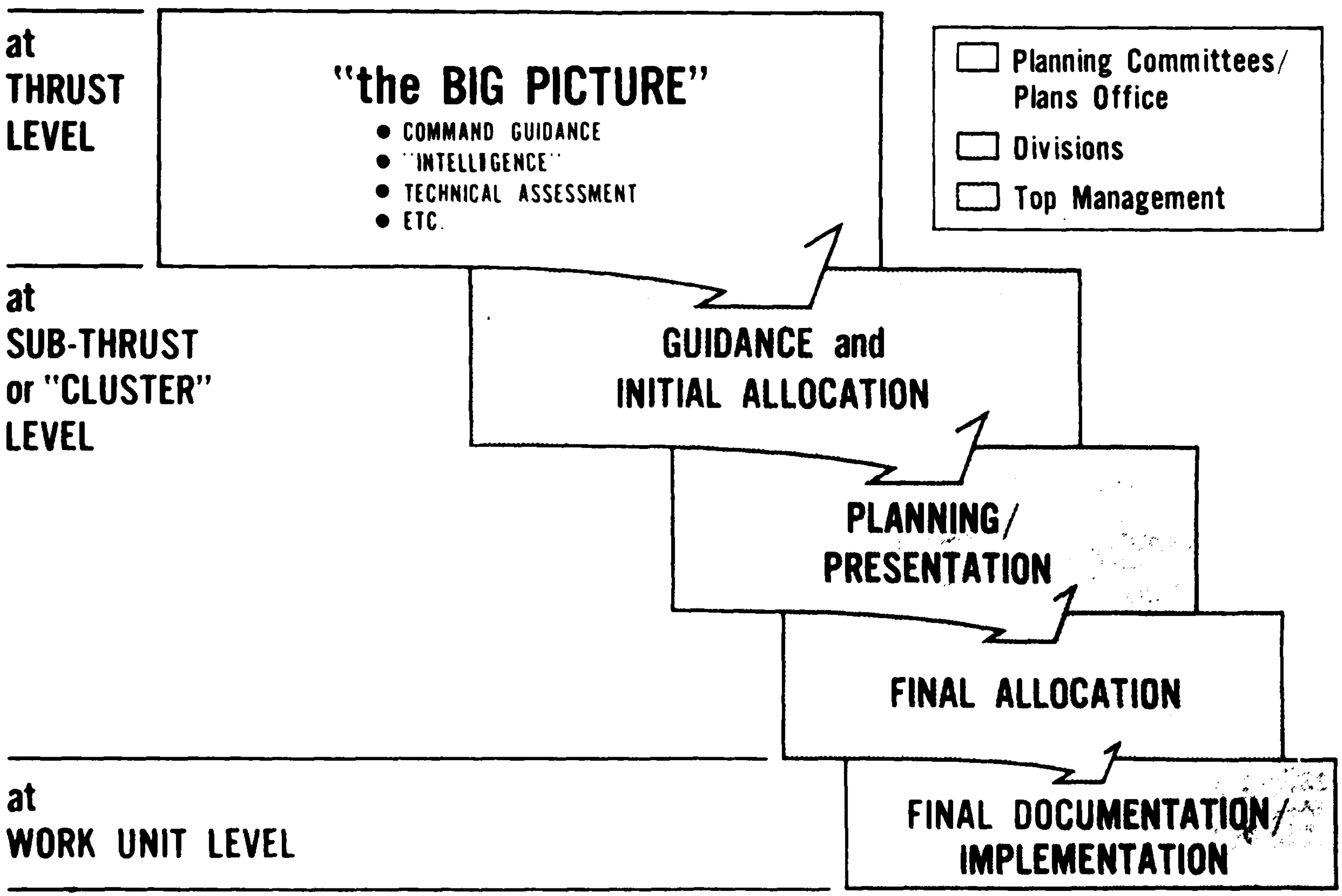


FIGURE 2

The Air Force Astronautics Laboratory's program is organized into five Technical Thrusts: One for each of the three major rocket propulsion applications areas, i.e., ballistic missiles, air-launched missiles and space propulsion systems; one for propulsion technology which is (or will be) applied to several application areas; and one for non-propulsive space systems. The AFAL/AFOSR Basic Research (Program Element 61102F) program summary description is shown in Figure 3. The five Technical Thrusts are congruent with the five projects under the Laboratory's Exploratory Development Program Element (62302F). A summary of the 6.2 program is shown in Figure 4. Our Space and Missile Rocket Propulsion Advanced Technology Development (63302F) projects are aligned with our three applications oriented Technical Thrusts. A summary of the 6.3 program is shown in Figure 5.

A breakout of the exploratory development program to the subthrust, or cluster, level is shown in Figure 6. The area of the boxes is proportional to the amount of 62302F funds allocated for each cluster.

The rocket propulsion technology applicable to the Strategic Defense Initiative (SDI) is accomplished within the present sub-thrust structure of the Laboratory. However, the overall SDI technology development is under the auspices of a separate SDI Technology Office. The focal points, and their respective areas of responsibility, within the SDI Technology Office are shown in Figure 7.

6-9-5-1 A

AFRPL/AFOSR Basic Research....

OBJECTIVES

- Conduct Research in
  - New Energetic Compound Synthesis
  - C/C Processing Variables
  - Fracture & Aging Behavior
  - Energy Exchange Mechanisms
  - Chemical Kinetic Influences
  - Advanced Concepts
  - High Energy Density

TASKS

- Ingredient Synthesis
- Carbon/Carbon
- Structural Mechanics
- Combustion
- Plumes
- Solar Plasma
- Excited States
- Antiproton

FUNDING ($K)

PE	FY	86	87	88	89	90
61102F		2.0	2.4	2.6	2.7	2.8

PAYOFFS:

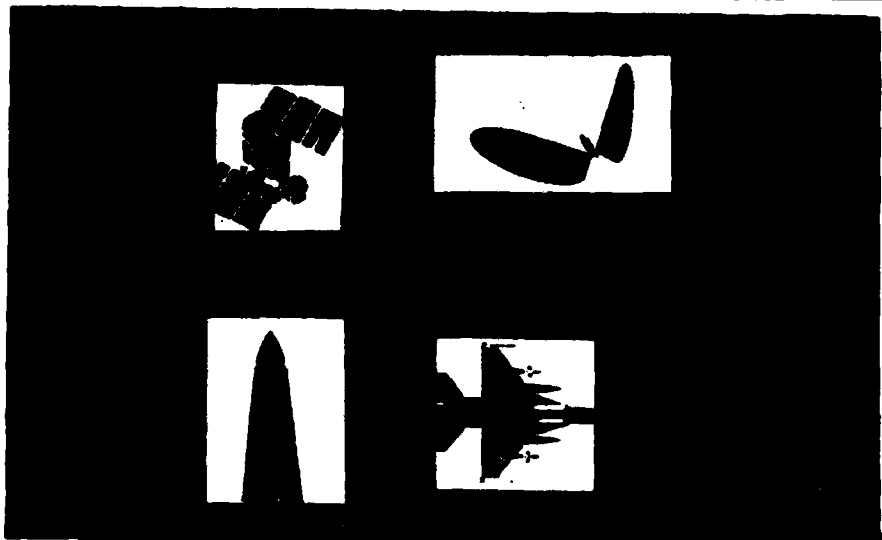
- Cleaner Design Alternatives
- Magnitude Gains in Usable Thrust
- New Knowledge for Technologies
- Peer Interactions with Lab S&E
- Transition Research Findings to 6.2 Dev.

02965

FIGURE 3

7-2-26-1 A

Rocket Propulsion 62302F....



THRUSTS:

- Space Propulsion
- Interdisciplinary Space Technology
- Air-Launched Missile Propulsion
- Ballistic Missile Propulsion
- Multiple Application Technology

FUNDING ($ × Millions):*

FY87	FY88	FY89	FY90	FY91
37.5	43.3	44.3	47.9	49.5

*FY88 PB

PAYOFFS:

- A/L Mission Range Increase
- Reduced Observables
- Survivable/Flexible Basing Modes
- Lower Cost/Higher Reliability
- More Payload to GEO
- 40% Increase in Satellite Life
- 75% Reduction in Radiator Weight
- Increase in ASAT Capability

03795

FIGURE 4

Space & Missile Rocket Propulsion (63302F)....

OBJECTIVES

- Integrate/Demonstrate Advanced Rocket Propulsion Technology Options
- Increase Mission Capabilities for Tactical and Strategic Weapons and Space Systems
- Improve Reliability and Maintainability at Reduced Cost and Risk

PROJECTS

- Air-Launched Missile Propulsion (6339)
- Space Systems Propulsion (6340)
- Ballistic Missile Propulsion (6431)

PAYOFFS

- Air-Launched Technology
  - 50% Increase Weapons Loadout/Range
- Space Systems Technology
  - 160% Payload Increase over IUS
  - 100% Payload Increase over Gentaur G
- Ballistic Missile Technology
  - 33% Throw-Weight Increase over SOTA

FIGURE 5

6-4-25-1 8

AFAL Exploratory Development Program....

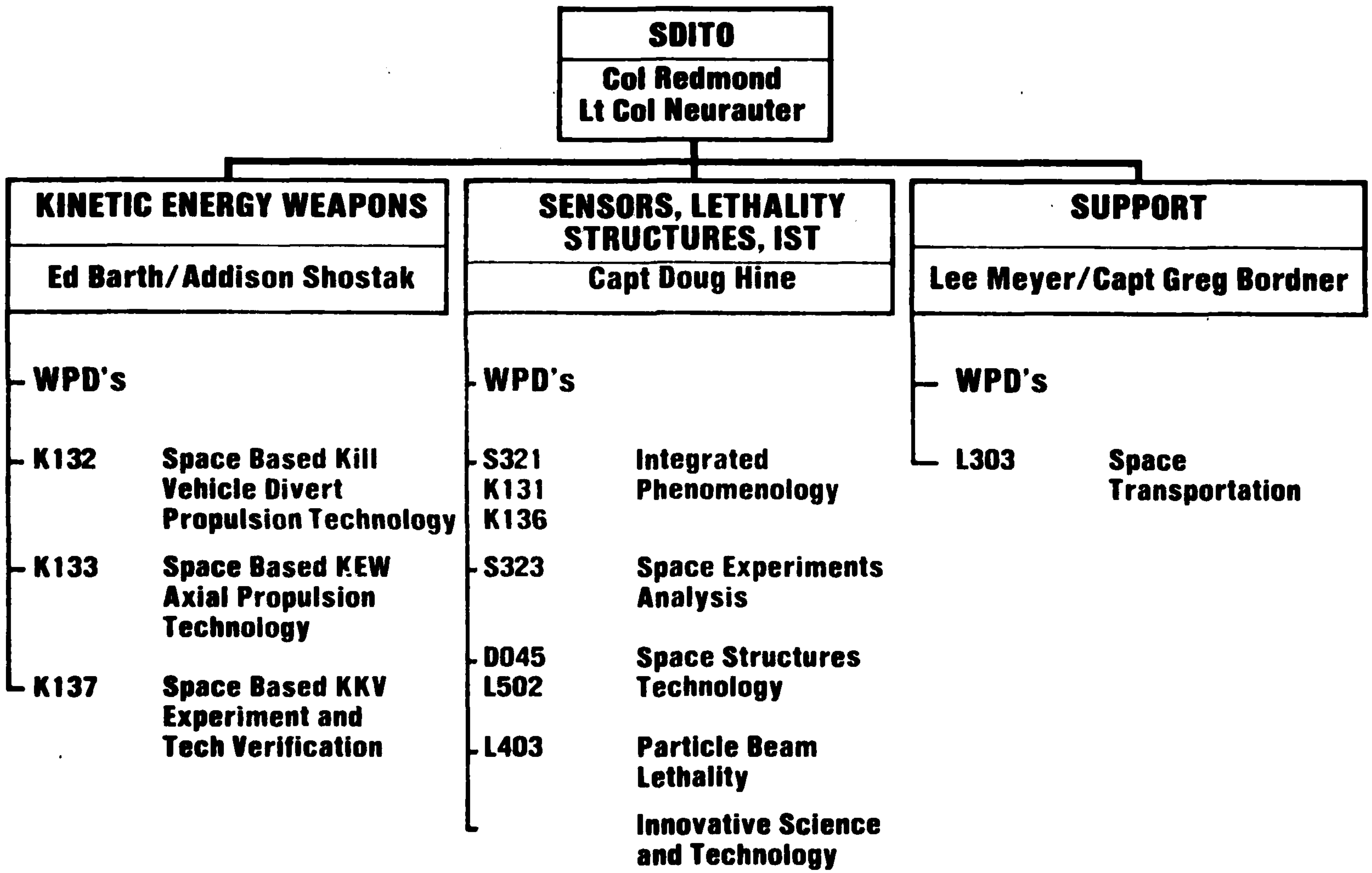
FY88 "President's Budget" -- Areas are Proportional to Funding Levels

SPACE PROPULSION	INTER-DISCIPLINARY SPACE TECH	BALLIS. MSL PROP.	AIR-LAUNCHED MISSILE PROP.	MULTIPLE APPLICATION PROPULSION TECHNOLOGY
LAUNCH VEHICLE PROPULSION	SPACECRAFT ENABLING TECHNOLOGIES	SERVICE LIFE	LOW SIGNATURE	APPLIED RESEARCH IN ENERGY STORAGE
ORBIT TRANSFER AND MANEUVERING PROPULSION	SPACECRAFT OPERATIONAL LOGISTICS	ADV BOOSTER TECH	IMPROVED PERFORMANCE MOTORS	IMPROVED SOLID PROPELLANTS AND FUNDAMENTALS
SIGNATURES/ANALYSIS	ASTRONAUTICS INITIATIVES	NOZZLE AND EXIT CONE TECH	RAMJET	COMBUSTION
ADVANCED SPACE PROPULSION			COMPONENT ASSURANCE	MOTOR STRUCTURAL INTEGRITY

FIGURE 6

TR331

AFAL SDI Focal Points....



03796

FIGURE 7

TECHNOLOGY PROGRAMS

A discussion of each of the Laboratory's Technical Thrusts is provided in the following paragraphs. The Technical Thrusts will be discussed in the order shown in the upper right quadrant of Figure 4.

1. Space Systems Propulsion Technology

The Space Systems Propulsion Thrust provides technology for all future space systems: launch vehicles, orbit transfer/maneuvering vehicles, and satellites. In addition, as in the past, technology from this thrust will be applied by the Navy, NASA and commercial industry to their space systems. This thrust is summarized and illustrated in Figures 8 through 12.

a. Objectives

The overall Space Systems Propulsion Technology Thrust is broken into the five clusters shown in Figure 8. Each of these clusters represents an area in which USAF requirements for advanced propulsion technology are being addressed. The efforts within the clusters are oriented toward achieving the overall thrust objectives shown in the upper right quadrant of Figure 8. The objectives of the various clusters include: (a) the transportation of larger, heavier payloads to orbit on a low cost, routine, and assured access to space basis through improved manufacturing and design utilizing advanced materials and engine concepts; (b) affordable space propulsion systems through improved performance, lighter weight and increased life orbit transfer and maneuvering capability; (c) advanced electric, solar, nuclear, and radically new propulsion systems having high performance, long life, and increased thrust.

b. Clusters

The three major clusters shown in Figure 8 will be discussed, with the exceptions being Space Propulsion Analysis and Signatures.

(1) Launch Vehicle Propulsion

This cluster is summarized in Figure 9. The purpose of this cluster is to develop the propulsion technology needed to enable affordable fully reusable launch vehicles as well as low cost expendable or partially reusable vehicles. The required increases in the engine thrust/weight ratio and specific impulse to enable single stage to orbit will be achieved through innovative design approaches and application of advanced materials. Low cost for the expendable and partially reusable systems will be achieved through automated manufacturing as well as innovative design. There are technology areas unique to both liquid and solid propulsion which will focus on improved performance/reduced weight and reduced acquisition/operations cost for both types of propulsion. The major goals for liquid systems are to develop and demonstrate component technologies for an advanced liquid oxygen/liquid hydrogen engine which delivers high trajectory effective specific impulse while being light weight and having long operational life with minimum maintenance. Reduced cost for both reusable and expendable liquid systems will be achieved by condition monitoring to save inspection and maintenance time, and by cost optimized design and fabrication approaches. The

Space Systems Propulsion....

OBJECTIVE

- Develop and Demonstrate Technology to Improve
  - Performance
  - Lifetime
  - Survivability
  - At Lower Cost

CLUSTERS

- Launch Vehicle Propulsion
- Orbit Transfer and Maneuvering Propulsion
- Signatures
- Space Propulsion Analysis
- Advanced Space Propulsion

PAYOFFS

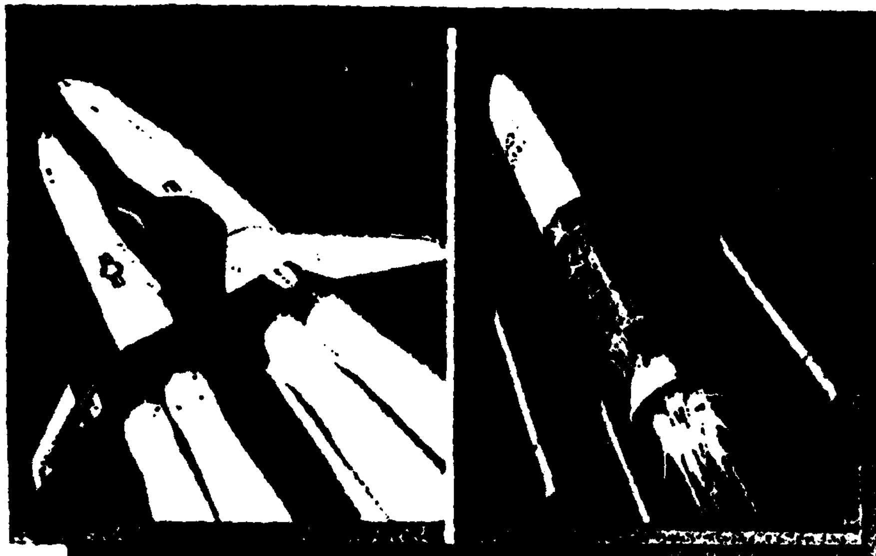
- Assured Access to Space
- Reliable and Effective Space Operations
- Improved Survivability
- Affordable Space Systems

FIGURE 8

7-4-17-5 C1

Space Systems

Launch Vehicle Propulsion....



OBJECTIVES/GOALS

- Increase Reusability/Decrease Processing Time
- Increase Trajectory Effective I_{SP} by 15 sec
- Increase Engine Thrust/Weight to 100:1
- Explore Innovative Design and Automated Manufacturing

TECHNOLOGY/CHALLENGES

- Define Design Concepts and Technology Demonstrator for Advanced O_2/H_2 Engine
- Apply Advanced Materials and Fabrication Techniques
- Verify Low Cost Design and Manufacturing Approaches

PAYOFFS/MILITARY SIGNIFICANCE

- Allow Affordable Fully Reusable Two Stage Launch Vehicle
- Building Block for Single Stage to Orbit
- Reduce Cost of Expendable Launch Vehicle
- Reduce Acquisition and Operations Cost of Solid Boosters

FIGURE 9

TR337

major goals for solid systems are to reduce recurring costs for both expendable and recoverable boosters by developing nozzleless concepts, low cost propellant, and designing motors to take advantage of automated fabrication and assembly. Performance improvement and weight reduction will be achieved by the application of advanced materials.

(2) Orbit Transfer and Maneuvering Propulsion

This cluster is summarized in Figure 10. The objective of the orbit transfer and maneuvering propulsion cluster is to develop and demonstrate the technology for advanced orbit transfer and maneuvering propulsion for future Air Force space applications. The cluster contains work in four major areas: Modular Storable Space Propulsion, Cryogenic Orbital Transfer Propulsion, Advanced Maneuvering Propulsion and Space Motor Propulsion technology. The modular storable space propulsion area is dedicated to a high performance pump fed N_2/O_4/MMH 3750 lbf engine and associated feed system. As the word modular implies, the technology has wide application and can be customized to each user's needs by adding more tanks or more engines to meet specific mission needs. The technology offers an increase in payload to GEO of 75 percent from the Space Transportation System over the current IUS and increased maneuvering capability of 40 percent over state-of-the-art pressure fed systems. The engine and propulsion system are very compact and provide an optimum design for integral propulsion systems of current Air Force interest.

The cryogenic orbital transfer propulsion area is directed toward the development of a low thrust high performance LOX/H_2 500 lbf pump fed engine and a compact feed system. The compact feed system uses a toroidal liquid oxygen tank to achieve a very short stage length. The resulting propulsion system has the potential capability of carrying approximately 14,000 lbm to GEO from the Space Transportation System with a short 20 foot stage length. The low thrust cryo engine provides a low acceleration delivery for large space structures.

The third area of emphasis is the Advanced Maneuvering Propulsion effort. This area is dedicated to improving maneuvering capability for low thrust (10 to 100 lbf) maneuvering systems.

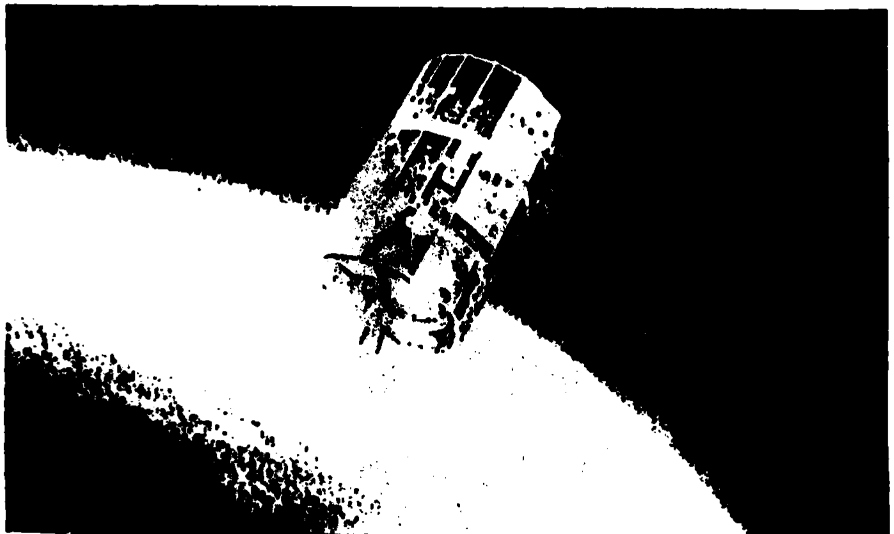
The fourth area of emphasis is the space motor propulsion technology area. Primary emphasis is on demonstrating space storage of solid rocket motors. Areas of investigation include radiation, temperature, and vacuum effects. This technology will allow the use and development of solid rocket motors for on orbit storage and sparing of satellites.

(3) Advanced Space Propulsion

This cluster is summarized in Figure 11. The Advanced Space Propulsion cluster pursues propulsion concepts that offer performance capabilities much greater than present chemical systems. Attaining specific impulses greater than 800 seconds and offering broad thrust ranges for a variety of mission applications are primary goals. These higher performance technologies increase payload capabilities while helping reduce operational costs. The cluster consists of four technology areas or sub clusters.

6-4-25-1 C22

Orbit Transfer and Maneuvering Propulsion....



OBJECTIVES/GOALS

- Demonstrate Modular Storable Space Propulsion
- Demonstrate Cryogenic Orbital Transfer Propulsion
- Develop Advanced Maneuvering Propulsion
- Demonstrate Space Storage of Solid and Liquid Propellants

TECHNOLOGY/CHALLENGES

- Thrust Chamber Heat Transfer and Durability
- Turbomachinery Durability and Performance
- Tank and Feed System Fluid Dynamics
- Space Storability of Solid and Liquid Propellants

PAYOFFS/MILITARY SIGNIFICANCE

- Provide Assured Access to Space
- Increase GEO Payload from STS (75-200%)
- Increase Flexibility (Multistart, Storage on Orbit, 40% Increase of Maneuverability)
- Increase Survivability (Maneuverability, Storage)
- Low Thrust Transfer Capability (0.5-0.2g)

TR353

FIGURE 10

Space Systems
Advanced Space Propulsion....

OBJECTIVES/GOALS

- Develop Reduced-Cost High Performance Advanced Orbit Transfer and Maneuvering Propulsion
  - Nuclear Propulsion
  - Electric Propulsion
  - Solar Propulsion
- Identify and Evaluate Revolutionary Space Propulsion

TECHNOLOGY/CHALLENGES

- High Performance ($I_{SP} > 800$ sec)
- Long Life/Reliability
- High Efficiency

PAYOFFS/MILITARY SIGNIFICANCE

- Reduces Cost of Current Missions
- Enables New Missions
- Increase Payload Mass to GEO Capability (Twice that of Chemical SOA)

TR357

FIGURE 11

The nuclear propulsion sub-cluster's primary effort is in support of the Project Forecast II nuclear propulsion effort. In 1986, contracts were initiated to develop nuclear propulsion system point designs for a nuclear orbit transfer vehicle. The result of these studies will focus the Project Forecast II effort toward a planned transition into a 6.3 effort. Future plans in nuclear propulsion continue with study efforts to identify technological advances in materials, nuclear fuel configurations, and reactor designs to increase the performance potential of nuclear propulsion systems.

The electric propulsion sub-cluster continues primary, near-term emphasis on arcjet propulsion. A contractual effort to develop a 30 kw arcjet based on state-of-the-art technology is well underway. An effort to develop an in-house arcjet test capability is in the planning and designing phases. An arcjet electronics effort headed for completion in FY 88 will support overall arcjet development leading to a space test. Efforts in the area of magnetoplasmadynamic (MPD) thruster research continue with an in-house effort to characterize pulsed thruster performance with continued support to Princeton University to seek performance improvements in the state-of-the-art MPD. Out year efforts in steady state MPD thruster development are planned with the advent of higher space power availability.

In the solar propulsion sub-cluster, the first firings of a solar rocket in the new in-house facility demonstrated 600 Isp. Future plans include continued characterization of the thruster in the in-house facility and developing this thruster technology for a future space test. Concentrator efforts will continue for developing deployable concentrators with high concentration ratios and accurate pointing mechanisms. Future efforts for advanced concentrator and thruster technology including concepts such as holographic concentrators and porous disc thruster are planned.

The 21st century concepts sub-cluster continues to seek advances in the basic sciences that may be applicable to propulsion. Identifying potential payoffs results in feasibility studies to seek applicability to Air Force propulsion needs. Future plans include a look at laser propulsion incorporating recent advances made in laser technology.

c. Payoffs

Figures 8, 9, 10, and 11 show some of the payoffs that can be realized through the application of rocket propulsion technology to future Air Force space systems. Figure 12 lists representative systems to which the technologies in this thrust can transition. There are many technologies involved, from advanced engines to thermal analysis for cryogenically-fueled OTVs, to optics and acoustics for engine condition monitoring, to gas dynamics and radiation physics for exhaust plume signature characterization.

d. Funding

Table 1 shows the total funding that we plan to devote to the Space Systems Propulsion Technology Thrust through FY 89. Program Element 61102F is AFOSR Research, Program Element 62302F is for Exploratory Development, and Program Element 63302F is for Advanced Technology Development.

Space Systems Propulsion

Transition Targets....

- Advanced Launch Vehicles
  - SSTO, Low Cost Expendable, HLLV
- Satellite Systems
  - Defense Support Program (Advanced)
  - Global Positioning System (Block II, III; Advanced)
  - Defense Meteorological Satellite Program (-3; Advanced)
  - Defense Satellite Communications System (Advanced)
  - Milstar (Block Change)
  - Satellite Data System (Block Change)
  - Wide Area Surveillance Program (Block Change)

FIGURE 12

TR333

6-4-25-1 C4a

Space Systems Propulsion

Transition Targets, (Cont'd)....

- Advanced Upper Stage Function
  - Imbedded Propulsion
  - Advanced Spacecraft Propulsion System (ASPS)
  - Orbit Transfer Vehicles (Expendable/Reusable)

- Forecast II
  - Advanced Heavy Lift Space Vehicle (PS-24)
  - Space-based Reusable Orbit Transfer Vehicle (PS-28)
  - All Systems Requiring Orbit Transfer
  - High Isp Particle Bed Nuclear Propulsion (PT-2)

FIGURE 12 (continued)

TR333a

TABLE I, SPACE SYSTEMS PROPULSION FUNDING ($K)

PROGRAM ELEMENT	FY 87	FY 88	FY 89
61102F	400	417	150
62302F	6,715	6,612	6,800
63302F	5,200	5,200	8,400

e. Future Plans

Planned future areas of work within the Space Systems Propulsion Technology Thrust are listed in Figures 13 through 15.

2. Interdisciplinary Space Technology

Interdisciplinary Space Technology focuses on integration of multiple disciplines to produce technology which provides the link between key propulsion and non-propulsive components of space systems in order to develop a total system. This thrust is illustrated and summarized in Figures 16 through 20. Efforts in this thrust fall under three areas: Spacecraft Enabling Technology, Spacecraft Operational Logistics, and Astronautics Initiatives.

a. Objectives

As shown in Figure 16, the intent of this thrust is to provide advanced technologies which will allow the U.S. to do a great many more things in space and to do these things at lower cost and free of obstruction from aggressive enemy action. This technology is being developed in three sub-thrusts: spacecraft enabling technologies, spacecraft operational logistics, and astronautics initiatives. Enabling technologies include large space structure dynamics and control and advanced space radiators for heat rejection of high power sources. Spacecraft operational logistics includes fluid management for propellant transfer in a zero-g environment and reuse/resupply for extended mission life and lower life cycle costs, as well as of the characterization of electric propulsion contamination potential. The astronautics initiatives sub-thrust was instituted this year as a means for handling new technology programs in response to the broadened charter associated with becoming the Air Force Astronautics Laboratory. These new programs, fundamentally extensions of current expertise in the laboratory, will address advancements in spacecraft structural and design technologies, the application of solar concentrators to solar dynamic power systems, and automated management of production and launch operations.

b. Clusters

Each of the three clusters shown in Figure 16 will be discussed.

(1) Spacecraft Enabling Technologies

The growing need for space systems in the role of space control, force enhancement, and force application calls for several concepts that are very large, require great quantities of power and call for, in general, a more survivable architecture. Examples of spacecraft enabling technologies being pursued at the Laboratory are summarized in Figure 17. These technologies will enable major capability increases in USAF systems.

The challenges are as shown in Figure 17. We need to diminish the fluid loss in a Liquid Droplet Radiator (LDR), both to reduce the amount of reserve fluid that needs to be carried into orbit and to minimize the amount of contamination caused to the spacecraft by the radiator. Future USAF Large Space Systems (LSS) will rely on both thrusters and linear torquers for slewing and surface control; we must demonstrate control algorithms that integrate these two

Space Systems

Launch Vehicle Propulsion....

TECHNOLOGY PROGRAM PLAN FY87-92

- Advanced O_2/H_2 Engine
- Advanced Materials
  - Lightweight
  - High Temperature
- High Energy, Clean Solid Propellant
- Design Concepts for Low Cost
- Reduced Production and Operations Cost

FIGURE 13

TR342

6-4-25-1 C24

Space Systems

Orbit Transfer & Maneuvering Propulsion....

TECHNICAL PROGRAM PLAN FY87-92

- Modular Storable Space Propulsion (N_2O_4/MMH)
  - XLR-132 Engine
  - Feed System
  - Reusability
- Cryogenic Orbital Transfer Propulsion (O_2/H_2)
  - XLR-134 Engine
  - Feed System
- Advanced Maneuvering Propulsion
- Propellant Storability
  - Liquids
  - Solids

TR354

FIGURE 14

7-4-17-5 C21

Space Systems

Advanced Space Propulsion....

TECHNOLOGY PROGRAM PLAN FY88-92

NUCLEAR PROPULSION

- Pursue PF-II Nuclear Propulsion Program
- Advance Nuclear Propulsion Technology

ELECTRIC PROPULSION

- Develop State-of-the-Art Arcjet
- Develop Steady State Magnetoplasmadynamic Thrusters
- Complete In-House Arcjet Facility

SOLAR PROPULSION

- Develop Concentrator Technology
- Develop Engine Technology for Space Test

21st CENTURY PROPULSION

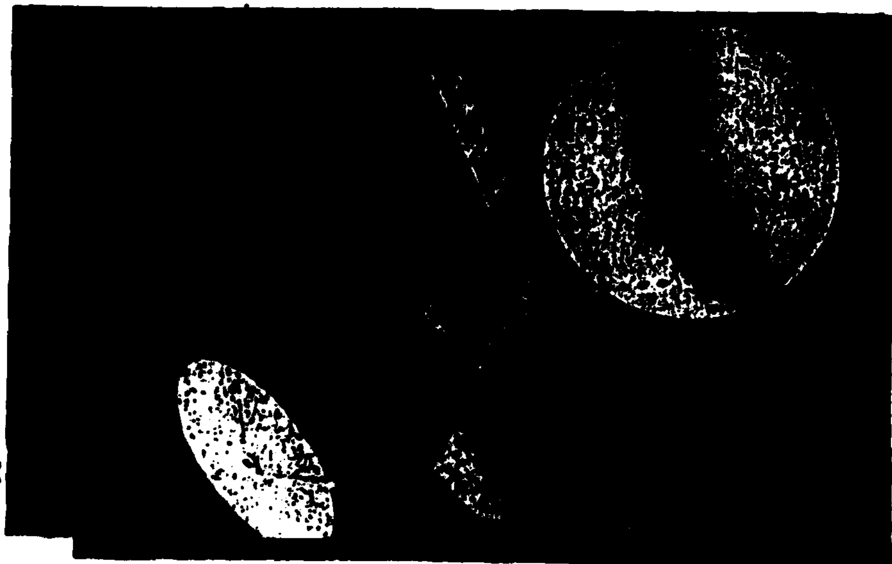
- Pursue Fusion Propulsion Technology
- Pursue Laser Propulsion Technology

TR362

FIGURE 15

G-4-25-1 E2

Interdisciplinary Space Technology....



OBJECTIVE

- Provide Technology Necessary For:
  - Survivability
  - Control of Space

CLUSTERS

- Spacecraft Enabling Technologies
- Spacecraft Operational Logistics
- Astronautics Initiatives

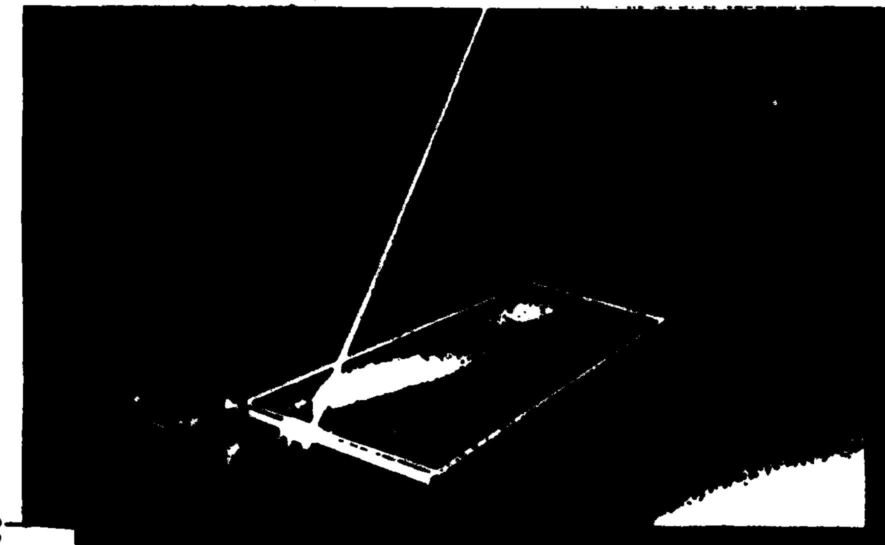
PAYOFFS

- Improved Survivability
- Lower Cost Space Operations
- Enhanced Space Superiority

FIGURE 16

TR008

Interdisciplinary Space
Spacecraft Enabling Technologies....



OBJECTIVES/GOALS

- Demonstrate Identification and Control of Highly Complex/Flexible Systems
- Simulate Deployment of Highly Complex/Flexible Systems
- Demonstrate Liquid Droplet Radiator in Micro-Gravity

TECHNOLOGY/CHALLENGES

- Distinguishing/Controlling Closely Spaced, Low Frequency Structural Modes
- Simulate Mass Flow and Ring Structures in LSS Deployment
- Minimize Fluid Loss in Liquid Droplet Radiators

PAYOFFS/MILITARY SIGNIFICANCE

- Enable Space-Based Radar
- 75% Reduction in Radiator Weight to Enable High Power Space Systems
- Lower Cost Space Operations

TR369

FIGURE 17

different controllers. Deployment of future LSS will involve significant mass flow (as in mesh unreeling from a roller) and ring structures; to simulate these in a general code is another of the technical challenges we face. To meet these challenges, we have set the goals shown.

We will demonstrate a subscale LDR in zero-gravity, proving feasibility of generating and efficiently collecting droplets in the absence of gravity. We will build upon our already completed work in the Flexing Structure Control lab experiment and demonstrate integration of thrusters and linear torques to control the structure. We will develop a computer code capable of quickly and accurately modeling the deployment of future USAF LSS. Achieving these goals enables the payoffs shown.

For megawatt power level space systems, an LDR will be four times lighter than an alternate radiator for the same heat rejection. Accurate sensing and control of the surface shape combined with rapid slewing capability will enable wide area surveillance. Reliable simulation of LSS deployment will enable a reduction in the number of expensive space experiments to achieve the same confidence of successful operational deployment. Lower weights and higher survivability directly translate to lower cost space operations for the Air Force.

(2) Spacecraft Operational Logistics

The expanding role of space in defense, will mean significant space operations. Examination of operations exposes critical technical needs which must be addressed to allow viable, flexible, enduring, and affordable space exploitation. The interdisciplinary technology areas addressed in this area include contamination, reuse and resupply, and long term cryogenic storage. These technologies are summarized in Figure 18.

The spacecraft operational logistics cluster covers the areas of fluid management, long-term cryogenic storage, and electric propulsion contamination assessment. The overall goal of these efforts is the extension of spacecraft on-orbit mission capability.

Long-term cryogenic storage efforts are focused principally on passive thermal control. Technologies in insulation, tank supports, thermal barriers, and thermodynamic vent systems are being pursued. Integrated flight type component tests will be conducted in the out years to demonstrate technology readiness. Innovative concepts applicable to active thermal control are being pursued on an as-available basis utilizing Small Business Innovative Research funding.

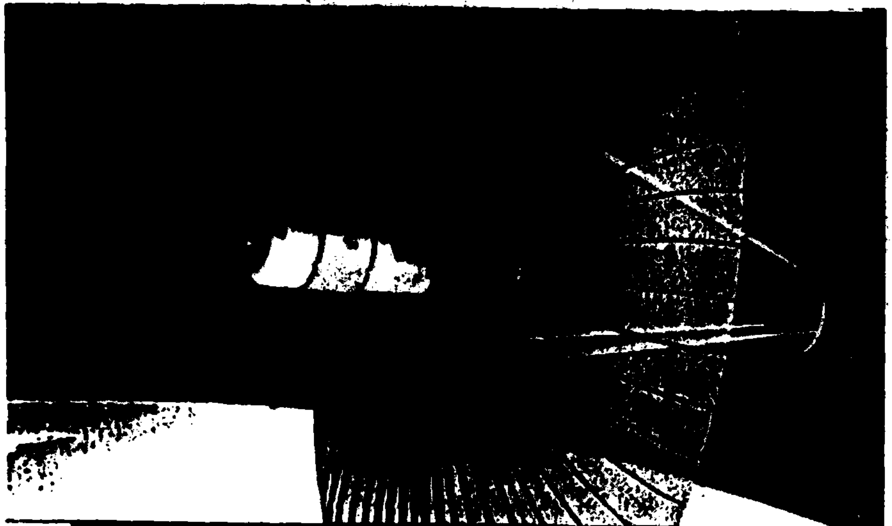
Under the fluid management program, propellant venting technologies and propellant behavior in a low-g environment are being investigated. A Shuttle middeck experiment will determine fluid characteristics in a torus tank. Also, several venting techniques have been identified for resupply missions. Flight-type demonstrations will be required before the technology can be applied on any resupply mission.

The objective of the electric propulsion contamination effort is to measure the plume flowfield and exhaust constituents in a simulated space environment. Results from these efforts will be used to predict the contamination of a spacecraft when electric thrusters are used for orbit transfer, stationkeeping or attitude control functions.

7-4-17-5 E10

Interdisciplinary Space

Spacecraft Operational Logistics....



OBJECTIVES/GOALS

- Improve In-Space Cryogenic Storage Capability
- Develop Satellite Resupply Technology
- Characterize Arcjet Plume Environment and Minimize Mission Impacts

TECHNOLOGY/CHALLENGES

- Reduce Heat Leak and Refine Applications to Large Systems
- Demonstrate Satellite Resupply Components
- Establish Valid Contamination Data Base

PAYOFFS/MILITARY SIGNIFICANCE

- Improved Operational Flexibility
- Extended On-Orbit Life for Cryogenic and Storable Fluid Systems
- Reduce Environment Contamination
- Reduce Space Vehicle Replacement Requirements/Costs

TR381

FIGURE 18

(3) Astronautics Initiatives

The Astronautics Initiatives are directed toward expanding the Astronautics Laboratory role in the Interdisciplinary Space Technology area. The challenges addressed are as shown in Figure 19. The projects chosen were based on USAF needs for lightweight, dimensionally-stable, controllable spacecraft structures, for high-power, lightweight space power systems and lower launch-operation costs. They were also chosen because they represent extension and transition of technologies and in-house capabilities developed for rocket propulsion application. Thus, the advanced spacecraft structures area was selected as the major emphasis for this cluster. We recognize that the Flight Dynamics and Materials Laboratories have efforts in this area, as does NASA. We will work with these organizations to ensure that our work does not duplicate but compliments and extends their efforts. We are aiming at taking advantage of advancements in both aircraft and rocket structures and applying them to spacecraft structures.

Our work in composites for spacecraft structures will initially concentrate on the application of carbon/carbon materials to structures which require light weight coupled with high stiffness and minimial outgassing on orbit. Analysis, fabrication, and testing will be done in-house as well as on contract. We will also explore the application of composites to large booster payload shrouds. We will extend the thin film technology work done for other applications to structures which can be made in space. This can provide a means of transporting the structural material as a liquid which can be relatively compact and dense and forming it into a very lightweight structure in space. Smart structures employing embedded sensors and actuators to provide control and/or health assessment of spacecraft structures will be developed. Coatings and adhesives will be developed to provide longer life and more reliable structures which will be easier to repair in space.

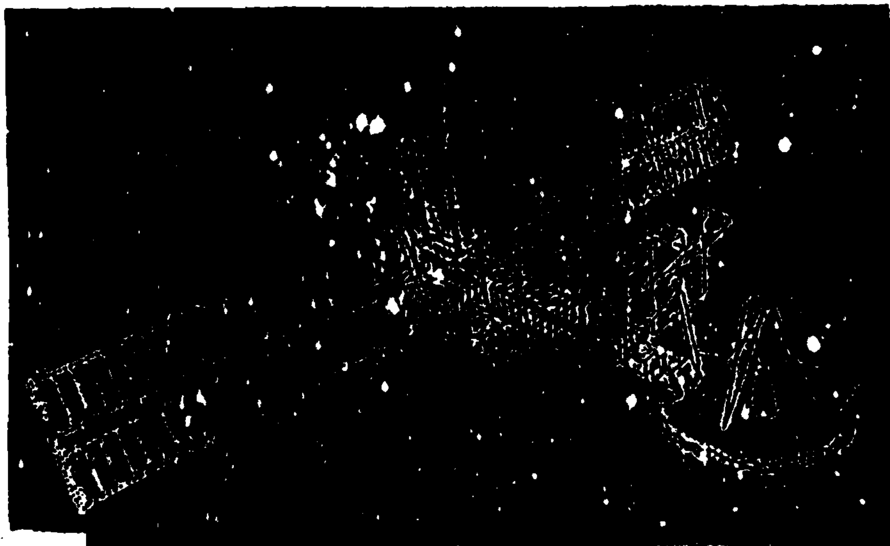
A spacecraft design and analysis tool will be developed which will emphasize the areas of interest to the Astronautics Laboratory and allow us to assess the payoffs of changing technology in terms of systems level payoffs. We will capitalize on our work in solar propulsion to study the application of its collector and heat exchanger technology to dynamic space power systems. Starting with a study, we will work towards automating the management of information to reduce the very large costs of preparing and controlling the massive amounts of paperwork involved in booster production and launch operations.

c. Payoffs

Figures 16, 17, 18, and 19 show some of the payoffs that can be realized through the application of the interdisciplinary space technology of this thrust area. Figure 20 lists representative systems to which the technologies of this thrust could transition. Many of the technologies are high risk, high payoff areas. However, without these technologies, many of the complex future systems that are projected today will not be possible. Their advancement will require the participation of a broad spectrum of government and industry organizations and people.

Interdisciplinary Space

Astronautics Initiatives....



OBJECTIVES/GOALS

- Demonstrate Advanced Spacecraft Structural Technologies
- Reduce Production/Launch Costs
- Identify Advanced Space Power Options
- Identify Key Astronautics Technology Gaps

TECHNOLOGY/CHALLENGES

- Adapt Advanced Materials to Spacecraft Designs
- Develop Intelligent Spacecraft Structures
- Develop Automated Management System
- Improve Solar Conversion Efficiency

PAYOFFS/MILITARY SIGNIFICANCE

- Reduce Spacecraft Weight by 60 Percent
- Enable Close Tolerance Control of Spacecraft
- Reduce Life Cycle Costs by 20 Percent
- Reduce Weight of Power System

TR394

FIGURE 19

Interdisciplinary Space Technology

Transition Targets....

- Satellite Systems
  - Defense Support Program (Advanced)
  - Global Positioning System (Block II, III; Advanced)
  - Defense Meteorological Satellite Program (-3; Advanced)
  - Defense Satellite Communications System (Advanced)
  - Milstar (Block Change)
  - Satellite Data System (Block Change)
  - Wide Area Surveillance Program (Start-Up; Block Change)
  - Advanced Surveillance, Radar Systems
- Antisatellite Systems (Air-Launched, Space-based)
- Reusable Orbit Transfer Vehicles

FIGURE 20

6-4-25-1 E4a

Interdisciplinary Space Technology

Transition Targets, (Cont'd)....

- Forecast II
  - Space-based ASAT System (PS-25)
  - Manned Space Station (PS-27)
  - Space-based Reusable Orbit Transfer Vehicle (PS-28)
  - Space-based Space Surveillance (PS-32)
  - Space Power (PT-5)
  - Adaptive Control of Ultra-Large Arrays (PT-15)
  - Satellite Protection (PT-19)

FIGURE 20 (continued)

TR010a

d. Funding

Table 2 shows the total funding for this thrust through FY 89. Program Element 62302F is for Exploratory Development.

e. Future Plans

Planned future areas of work within the Interdisciplinary Space Technology Thrust are listed in Figures 21 through 23.

TABLE 2, INTERDISCIPLINARY SPACE TECHNOLOGY FUNDING ($K)

PROGRAM ELEMENT	FY 87	FY 88	FY 89
62302F	1,795	3,775	4,195

7-4-17-5 E5

Interdisciplinary Space
Spacecraft Enabling Technologies....

TECHNOLOGY PROGRAM PLAN FY87-92

- Develop Advanced Sensors and Actuators for Large Space System (LSS) Control
- Demonstrate Shape Control of a 3D LSS
- Complete Deployment Dynamics Computer Simulation
- Demonstrate System Identification, Slewing, and Vibration Suppression Technologies on ASTREX
- Conduct In-House System Identification Experiments
- Demonstrate Liquid Droplet Radiator (LDR) Collector in Micro-Gravity
- Demonstrate Direct Contact Heat Exchanger in Micro-Gravity

TR373

FIGURE 21

7-4-17-5 E14

Interdisciplinary Space

Spacecraft Operational Logistics....

TECHNOLOGY PROGRAM PLAN FY87-92

- Long Term Cryogenic Storage
- Middeck Propellant Management Experiment
- Venting Components Technology Demonstration
- Arcjet Plume/Contamination Diagnostics

FIGURE 22

TR385

7-4-17-5 E21

Interdisciplinary Space
Astronautics Initiatives....

TECHNOLOGY PROGRAM PLAN FY87-92

- Develop Advanced Spacecraft Structural Technologies
  - Composites/Thin Film
  - Actuators/Sensors
  - Coatings/Adhesives
  - Design/Analysis
- Study Solar Dynamic Power Systems
- Develop Automated Management System

FIGURE 23

TR395

3. Air-Launched Missile Propulsion Technology

The Air-Launched Missile Propulsion thrust develops the propulsion technology needed for air-to-air and air-to-surface missiles. This technology will provide future missile systems with the following benefits: increased survivability, increased lethality, increased reliability, increased age life, and increased cost effectiveness. The principal areas of emphasis are an understanding and manipulating of plume signatures, improving performance and providing energy management. Technology from this thrust has also been adapted by the Navy and Army in their tactical missiles. This thrust is illustrated and summarized in Figures 24-26.

a. Objectives

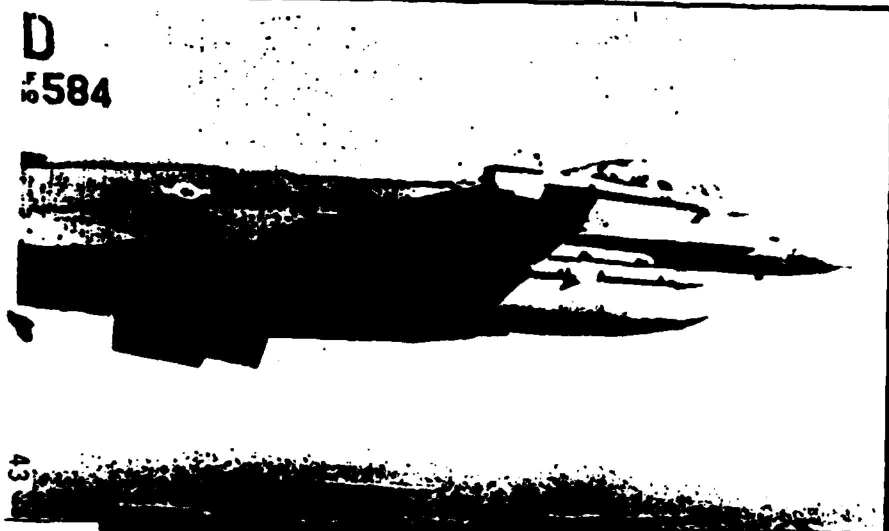
The overall objectives of this thrust are presented in Figure 24. The operational benefits being provided in signature, survivability, range, and fire power are necessary in order to overcome the numerical superiority and increased threat our forces are facing. By reducing our missile signatures (infrared, ultraviolet, visible and radar) and improving missile performance we will increase missile flexibility and lethality. These missile improvements, added to increases in standoff range and fire power equate to increases in aircraft survivability and mission performance (e.g., more munitions on target, more kills per pass, higher sortie rates, etc.). As the above operational benefits are being provided, it is also a major objective to provide logistics benefits in reliability, age life and costs. The work in this thrust is performed under five subthrusts or clusters as outlined in Figure 24.

b. Clusters

The first cluster involves "Low Signature Motors." This cluster addresses low signature propellant development and plume analysis for air-launch systems. The objectives are to predict, analyze and minimize plume signatures, to improve the performance and reduce the costs and hazards of minimum signature propellants, and to establish meaningful hazards criteria for determination of detonable/nondetonable propellants. As missile airframes become "stealthier," the radar cross section (RCS) of the plume plays a greater role in enemy detection of the missile. To enable prediction and advantageous manipulation of the plume RCS, measurements need to be accomplished to validate RCS codes. Thus, the missile's kill probability is enhanced, as is the launching aircraft's survivability. Currently, minimum smoke propellants are more hazardous than reduced smoke propellants. However, minimum smoke propellant contrails are not visible below 27,000 feet in the European theatre, while reduced smoke propellant contrails are visible 50 percent of the time below 20,000 feet in the same theatre. A solid rocket motor may have a propellant web thickness greater than the propellant's critical diameter (that diameter which will support a steady-state detonation), be Class 1.3 by the Naval Ordnance Laboratory's card gap test, and yet have the propensity to detonate. An ability to clearly distinguish detonable/nondetonable propellants is greatly needed and will improve safety of handling and use of missiles. It will also aid in the determination of numbers of missiles to be stored near the launching aircraft and will enhance joint service weapons deployment and NATO theater use of advanced weapons. Technology areas being investigated to provide improved plume prediction and analysis are

6-4-25-1 B2

Air-Launched Missile Propulsion....



OBJECTIVES

- Reduce Missile Signature
- Provide Mission Flexibility
- Improve R&M
- Increase Firepower

CLUSTERS

- Low Signature
- Improved Performance Motors
- Technology for Ramjets
- Propulsion Analysis
- Component Assurance

PAYOFFS

- Increased Survivability
- Expanded Range/No Escape Zone
- Lowered Missile O&M Costs
- Improved Loadout

FIGURE 24

TR077

experimental acquisition of plume radar cross section, particulate, and shock structure data to validate and upgrade existing plume computer codes. Technology areas being investigated to improve the performance and reduce the hazards of minimum signature propellants are the development of propellants capable of operating at high pressures, and demonstration of propellants possessing Class 1.3 hazards classification.

The goal of the second cluster "Improved Performance Motors" is to investigate and develop new technologies, or optimize the use of current technologies, in order to improve the performance of motors for air-launched missiles. The programs in this cluster will result in motors with more efficient propulsion packaging than the current state-of-the-art, improved aerodynamic performance, an order of magnitude reduction in observables, and increased overall motor performance. As a bottom line, this means more missile range for less motor weight as well as increased survivability and lethality of the missile.

Propulsion packaging has become increasingly important in recent years. Optimum missile airframes are aeroconfigured rather than circular in cross section. The current Non-Symmetric Motor Case program followed by the Aeroconfigured Motor program will develop the capability to use the rocket motor as an integral part of the aeroconfigured missile airframe rather than as a slide-in component. This will result in a significant boost in missile system performance. High pressure motor operation (2-5000 psi) offers a total performance improvement of 8 to 10 percent. This additional propulsive energy can be properly managed to yield a 30-40 percent range improvement, improved no-escape zone, and increased mission flexibility. The planned High Pressure Nozzle and High Pressure Operation Demonstration programs will enable future air-launched missiles to take advantage of the performance benefits of high pressure operation. Future air-launched missiles such as those mentioned in Project Forecast II and the Aerospace Defense Initiative may have propulsion requirements well beyond current capabilities. In an effort to look for the revolutionary performance improvements which may be needed to perform some of these missions we have begun looking at Advanced Propulsion Concepts for Air Launch. This cluster also includes projects to integrate these emerging component technologies into high performance motors as part of its advanced technology development, including the "High Performance/Low Observable Motor," and the "Future Missile Motor."

The third cluster is support "Technology for Ramjets." Responsibility for the development of ramjets lies within the Aero Propulsion Laboratory. However, ramjet operations depend upon solid rocket boosters to provide initial missile acceleration before ramjet takeover. It is the goal of this cluster to provide improvements in solid rocket technologies and the interfaces between the rocket and ramjet components. A short term goal is to reduce the booster volume while maintaining or improving the thrust level. This is being accomplished through the development of nozzleless boosters, increased performance propellant, and improved insulation.

"Propulsion Analysis" is the fourth cluster. The goal is to evaluate system requirements and propulsion capabilities to determine missile performance. This information is invaluable in directing technology developments for the future. Integrating various technology improvements with analytical models yields a figure of merit for achievable payoff gains.

The fifth cluster is "Component Assurance." The purpose of this cluster is to ensure that major new components under development can function reliably in the harsh air-launched environment. We also investigate ways to reduce cost so that advanced rocket motors can more readily be integrated into full-up systems. The programs in this cluster emphasize the "ilities," and successful completion of the programs will increase missile systems availability and reliability and could lead to longer service life. Since use of advanced composite materials can reduce rocket motor case weight by up to 40 percent over metal cases, we are studying the applicability of these materials to the air-launched environment. We are designing and building composite cases that will survive the air-launched captive carry and eject loads. We are also studying the effects of damage to composites that may be caused by in-process and field handling. We are integrating composite cases and other advanced technologies and demonstrating them in Advanced Technology Development programs. Ignition of tactical rocket motors must be reproducible and highly reliable, and the shock of ignition must not damage the propellant in the motor. We have programs to develop low shock igniters. We've also successfully demonstrated the "Laser Initiated Arm/Fire Device," which uses fiber optic and lasers to provide safer, more reliable safing, arming, and firing of tactical rocket motors. We have successfully transitioned laser ignition and arm/fire devices to industry where they have been demonstrated in numerous tactical systems. It is important to accurately predict the useful lifetime of rocket motors in order to minimize logistics and surveillance requirements; our programs address this need. We are increasing our prediction and surveillance efforts on AMRAAM and SPARROW. We plan to initiate programs to identify low cost processing techniques and to integrate low cost components into complete rocket motors. We are initiating a new project to better define the thermal and structural environments for missiles, on new aircraft (B-1, F-15E, ATF and ATB). Knowing the actual environments will allow us to better design the missiles for the new aircraft.

c. Payoffs

Specific payoffs available from air-launched missile propulsion are summarized in Figure 24. Range increases can be achieved through lower motor case weights, higher operating pressures, and solid propellant grain configurations when used with optimal logic controls. The increase in loadout is very important for more missiles per sortie. This will be achieved with conformal shaping and reduction/elimination of fin controls; development of thrust vector controls will negate the necessity for large fins. Decreased signatures result from advances in propellant formulation technology. In addition, the component assurance area will result in greater reliability, maintainability and lower O/M costs.

All of the above technology advances need to be demonstrated in flight demonstrations. A joint AFATL-AFAL-AFWAL program is designed to do this and is shown in Transition Targets (Figure 25). This is a very important program for all future air-launched systems. The modular features of the Advanced Missile Technology Integration (AMTI) test bed allow new components to be tested alone or in combination with other new components. In the rocket propulsion area, the leading edge technology to be tested in AMTI Phase I will be motors with a two-pulse capability to validate serviceability. Propulsion technologies for Phase II AMTI will include 1.3 minimum smoke propellant, advanced TVC, laser initiated

6-4-25-1 B4

Air-Launched Missile Propulsion

Transition Targets....

- Advanced Air-Launched Motor
  - Composite Case/Pulse Motor to SRAM II
- High Performance/Low Observable Motor
  - To AMTI Phase II
- Forecast II
  - Integrated Photonics (PT-11)
  - Active/Passive Broad Spectrum Signature Control (PT-18)
  - Autonomous Anti-Armor Weapons (PS-8)
  - Autonomous High Value Target Weapons (PS-9)
  - Long Range Air-to-Air Missiles (PS-12)
  - Advanced Aerospace Vehicle Weapons (PS-14)
  - Long Range Boost Glide Vehicle (PS-18)
  - Multi-Role Conventional Weapons (PS-47)

FIGURE 25

TR081

AFD, filament wound graphite composite case with high temperature resins capable of 2,000 psi operating pressures, multi-dimensional carbon-carbon integral throat entry nozzle, and optimal energy management logic. These technologies are the forerunners of spectacular gains that will be achieved in future air-launched missile systems, many of which have been identified in FORECAST II. The involvement with this major thrust and FORECAST II is shown in Figure 25.

d. Funding

Total funds to be expended in the Air-Launched Missile Propulsion Technology thrust from FY 87 through FY 89 are shown in Table 3. Program element 62302F is for the exploratory development efforts under Project 3148. Program Element 63302F covers the completion of an Advanced Technology Development (ATD) effort under Project 6339 to demonstrate advanced technologies in pulse motors, thermal barriers and composite cases. Also included in the 63302F area is the start an effort directed toward future air-launched missiles that will be integrated into the Phase II AMTI program. The 62203F effort is all the work supporting ramjet booster propulsion. Other funds are received to support ongoing system developments such as AMRAAM, AGM-130, HVM, SRAM-II and SPW. Man-Tech is 78011F funding; 62206 funding is from AFESC.

e. Future Work

The broad scope of future work for the three principal clusters, Low Signature, Improved Peformance Motors, and Component Assurance are shown in Figures 26, 27, and 28. These are not specific programs but general areas of investigation that will be investigated during the FY 88-92 time period.

4. Ballistic Missile Propulsion Technology

The Ballistic Missile Propulsion Technology thrust contains four clusters to develop technology for future USAF ballistic missile booster systems, upper stages and payload delivery systems. This thrust provides technology for improved performance in range/payload capability, increased reliability, reduced development risk and increased accuracy. This thrust is illustrated and summarized in Figures 29 through 32.

a. Objectives

The overall objectives include developing technologies that will increase booster reliability, enhance service life capability, reduce operation and maintenance costs, increase payload and range capability with reduced size missiles and enable new missions. These objectives will be met by investigating critical areas of solid propellant motor failure modes such as bonded interfaces, chemical migration and propellant aging. Components are being developed that will reduce the weight and volume of future ballistic missiles and that will enable high acceleration ICBM flight. Penetration-aids/re-entry vehicle propulsion will also be developed. New and innovative nozzle designs, simple and economic processing techniques, and characterization of nozzle performance and materials will increase reliability and reduce costs for future nozzles and exit cones. The work in this thrust is performed under four clusters as shown in Figure 29.

TABLE 3, AIR-LAUNCHED MISSILE PROPULSION FUNDING

($K)

PROGRAM ELEMENT	FY 87	FY 88	FY 89
62302F	3,168	2,790	3,180
63302F	1,800	2,700	2,300
62203F	276	125	-
62206F	-	125	200
65502F	256	30	-
78011F	-	-	1,200

7-4-17-5 B1

Air-Launched Missile Propulsion

Low Signature....

TECHNOLOGY PROGRAM PLAN
FY88-92

- Hazards Class 1.3 Propellant Development/ Demonstration
- Low Observable Propellant Development
- High Pressure Propellant Development
- Plume Measurement/Prediction

FIGURE 26

TR464

7-4-17-5 B11

Air-Launched Missile Propulsion

Improved Performance Motors....

TECHNOLOGY PROGRAM PLAN FY87-92

- High Performance/Low Observable Motor Development
- Integrate TVC and Pulse Motor Capability
- Aero Configured Rocket Motor Development
- High Pressure (2,000 - 5,000 psi) Motor Demonstration
- Advanced Propulsion Concepts for Air-Launch

FIGURE 27

TR476

Air-Launched Missile Propulsion

Component Assurance....

7-4-17-5 B17

TECHNOLOGY PROGRAM PLAN FY87-92

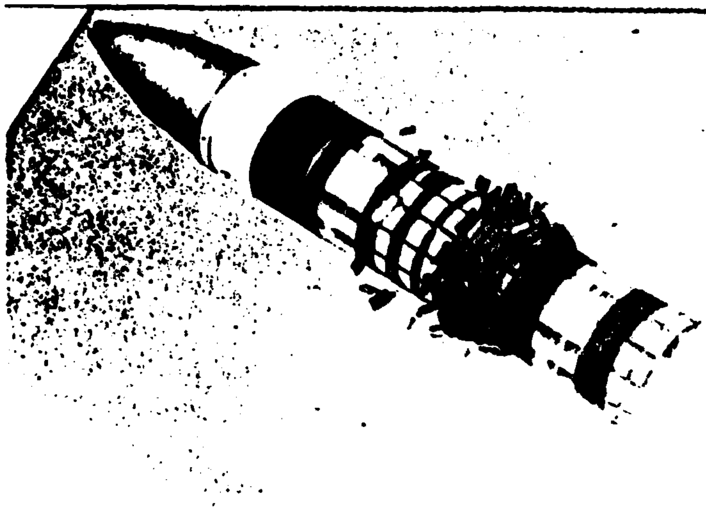
- Composite Case Durability Investigation
- Damage Assessment of Composite Cases
- Service Life Methodology Verification
- Low Shock Consumable Igniter
- Low Cost Process Evaluation Motor
- Determination of Aircraft Missile Environment

FIGURE 28

TR485

6-4-25-1 A2

Ballistic Missile Propulsion....



OBJECTIVES

- To Improve:
  - R & M
  - Component/Motor Performance
  - Manufacturing Cost/Process
- To Develop Technology for New Ballistic Missile Missions
  - High G
  - Relocatable Targets
  - Lethal Defense Penetration

CLUSTERS

- Ballistic Missile Service Life
- Advanced Booster Technology
- Nozzle & Exit Cone Technology
- Ballistic Missile Propulsion Analysis

PAYOFFS

- Increase Range and/or Throw-Weight
- Increase Service Life
- Increase Reliability of Missile Components
- Improve Missile Component Processing Techniques

FIGURE 29

TR409

b. Clusters

The clusters shown in the lower left quadrant of Figure 29 will be discussed.

(1) Service Life

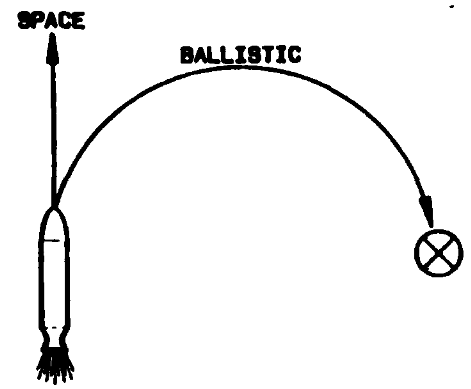
The Ballistic Missile Service Life cluster summarized in Figure 30 is responsible for developing technologies that will increase booster reliability, enhance service life capability, and reduce operation and maintenance costs. This is accomplished by investigating, identifying, and providing technology for controlling the processes which may lead to a high probability of failure in critical areas in a solid rocket motor. Bonded interfaces are being investigated to acquire technology to direct the development and evaluation of structurally superior bonded interfaces. Manufacturing and processing variables of high energy propellants will be investigated in order to identify and develop procedures that will ensure the production of reproducible propellants, liners, insulations and bond systems. To understand the interaction between the ballistics and the structural characteristics of a solid rocket motor, work is being done to understand how structural defects are initiated, how to identify these defects using computer tomography non-destructive evaluation technology, and understanding the effects of these defects.

(2) Advanced Booster Technology

The Advanced Booster Technology cluster summarized in Figure 31 develops solid rocket motor components that provide growth capability for future ballistic missiles in terms of throw-weight, range, increased basing flexibility, increased survivability, increased reliability and maintainability, and lower life cycle cost. A major technical issue in this cluster is the performance of motor cases. We have discovered new fiber/resin combinations that increase the case efficiency by up to 38 percent. Work is continuing in motor case technology to further improve case efficiency, reliability, processing, and damage assessment. Feasibility was demonstrated of critical Integrated Stage Concept (ISC) technologies in late FY 86. This concept was then transitioned to an advanced technology development program which will be conducted from FY 86 through FY 91. Studies and analyses indicate that applying the ISC to the SICBM can lower booster production costs 40 percent and increase throw-weight 18 percent or range 17 percent. Critical technologies for the high acceleration booster concept were identified. Propellant development for this type booster will be accomplished first, followed by the start of a motor component development program in the out years. Front-end propulsion technologies are also included in this cluster. Two programs have been completed that explored both liquid and solid technologies to reduce the weight of the post-boost propulsion system. Solid staged combustion (SSC) and gas driven intensifier technologies for advanced post-boost propulsion systems were demonstrated. The SSC concept can reduce system weight by 32 percent less than present solid gas generators. During FY 87 an advanced composite polar boss was developed which reduced manufacturing times by 67 percent.

6-4-25-1 A6

Ballistic Missile Service Life....



SERVICE LIFE TECHNOLOGY DEVELOPEMENT AND TRANSITION

OBJECTIVES/GOALS

- Manufacture Reliable Solid Rocket Motors
- Extend Service Life Capability
- Reduce Cost of Surveillance Program

TECHNOLOGY/CHALLENGES

- Developing Realistic Aging and Surveillance Technology
- Understand Propellant/Case Interfacial Bonding
- Develop Quantitative Nondestructive Evaluation of Motors
- Understand Strain/Structural/Ballistic Interaction

PAYOFFS/MILITARY SIGNIFICANCE

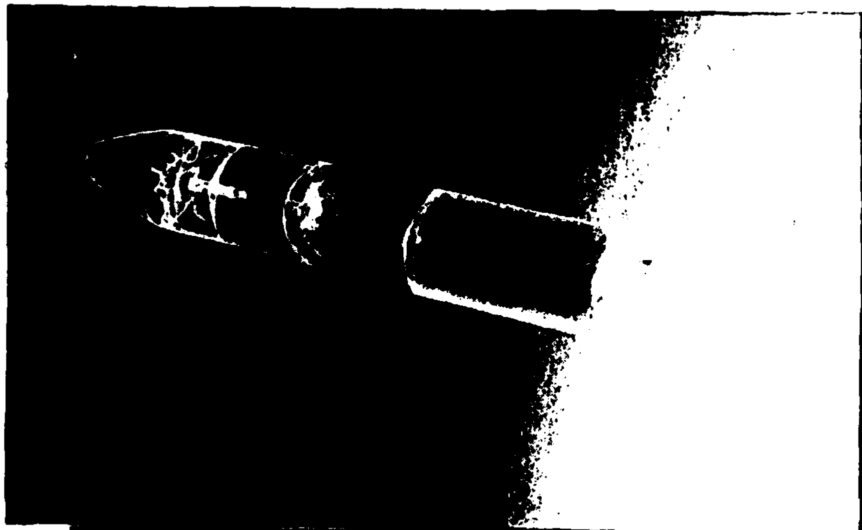
- Increased Life and Operational Reliability
- Reduce Assets Required for Aging and Surveillance
- Guidelines for Test/Deployment Decisions

FIGURE 30

TR044

7-4-17-5 A10

Ballistic Missiles
Advanced Booster Technology....



OBJECTIVES/GOALS
- Develop Motor Technologies for Advanced ICBM's
  - Develop Low Cost Components
  - Improve Motor Performance
  - Expand Propulsion Sys Capabilities
    - Boosters
    - Front-Ends
    - Pen Aids/RV's

TECHNOLOGY/CHALLENGES
- Application of Advanced Materials & Concepts
- Integrated Stage Technologies
- Propulsion for Penetrations Aids & Reentry Vehicles
- High-Acceleration Motors

PAYOFFS/MILITARY SIGNIFICANCE
- Increased Reliability & Maintainability; Lower Life Cycle Cost
- Additional Throw-Weight or Extended Range
- Improved Lethal Defense Penetration
- Improved Survivability Against Boost Phase Intercept

TR424a

.FIGURE 31

(3) Nozzle and Exit Cone Technology

The Nozzle and Exit Cone Technology cluster summarized in Figure 32 develops nozzle components for future ballistic missiles and space motors. The overall objective of this cluster is to increase the reliability of nozzles and exit cones. Work is being performed in the areas of nozzle materials, design and analysis, nozzle construction, processing science, and nozzle characterization and inspection. In-house studies are underway to develop a "proprietary free" carbon-carbon manufacturing process: to understand the carbon fiber structure, surface properties, oxidation rates, and surface morphology and porosity, and to develop a state-of-the-art thermal-structural analysis capability. We are actively participating in the development of an Advanced Rocket Nozzle Inspection System (ARNIS). The result of this program will be to employ the computer tomography inspection technique at a nozzle production contractor site. Two systems are to be made operational; one at Kaiser Aerotech and the second at Hercules/Bacchus. A large effort, both in-house and contract, is on-going to understand the significance of the flaws detected by computer tomography machines. In the area of nozzle fabrication, a new nozzle fabrication process was evaluated for use in the Small ICBM. The 3D French Novoltex advanced construction exit cone was selected for SICBM Stages II and III. Numerous disciplines are required to explore the art of nozzle and exit cone technology. This cluster helps much of the art become a science.

(4) Propulsion Analysis

The Ballistic Missile Propulsion Analysis cluster conducts analyses of future propulsion options for intercontinental ballistic missiles (ICBMs). The objective of this cluster is to quantify the advantages and disadvantages of different rocket propulsion options for ICBM propulsion in terms of payload, range, response time, and other critical propulsion parameters. An outstanding example of this kind of analysis was the work done on the Small ICBM (SICBM) for the Ballistic Missile Office. During this effort, analysts investigated the SICBM mission and differing solid fuel and liquid fuel propulsion options for a volume and weight limited missile. Future analysis efforts will focus on advanced, high-performance propulsion systems for ICBMs, such as fast-burn (high acceleration) concepts. Another promising area is nuclear propulsion. The usual product of an effort within this cluster is a study or report that is used to guide propulsion technology investment within the Air Force.

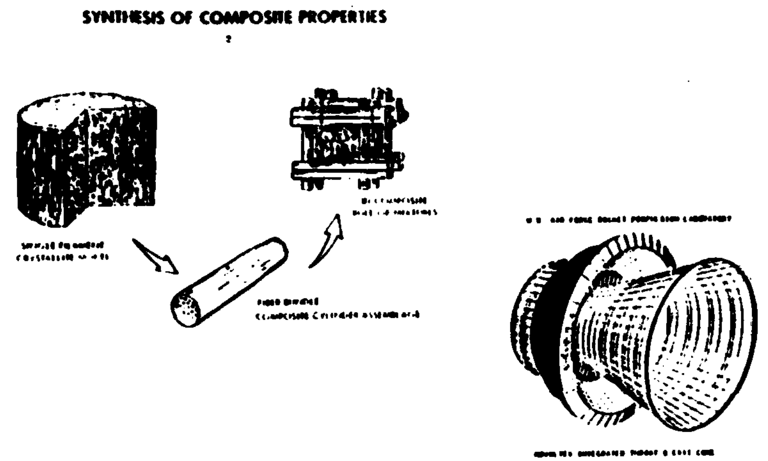
c. Payoffs

The Ballistic Missile Propulsion Technology thrust provides propulsion technology that enables the Air Force to maintain existing missile systems and to develop new missile systems to satisfy new mission requirements. Technical accomplishments in this thrust have given the Air Force the capability to predict the performance of the missile systems, minimize operational failures, and improve the performance of existing systems. The Advanced Strategic Missile Systems Office depends on the technical accomplishments of the Ballistic Missile Propulsion Technology thrust and assists AFAL in transitioning these technologies into systems. Figures 29, 30, 31, and 32 show some of the payoffs that can be realized by transitioning and applying the technologies being developed in this major thrust to Air Force space and ballistic missile systems. Figure 33 lists representative systems to which the technologies in this thrust can be transitioned.

6-4-25-1 A38

Ballistic Missile

Nozzle and Exit Cone Technology....



OBJECTIVES/GOALS

- Develop Reliable Carbon-Carbon Exit Cones
- Establish Proprietary Free Processing for Nozzle Components
- Provide Assessments for Prototype Nozzles
- Replace Degrading Insulators

TECHNOLOGY/CHALLENGES

- Quantify Inspections - Develop Accept/Reject Criteria
- Simplify C-C Processing
- Apply Emerging Noninovolute Nozzle Constructions
- Eliminate Potential Failure Modes

PAYOFFS/MILITARY SIGNIFICANCE

- Reduced Ballistic Motor Deveopment Time with Lower Risk Nozzles
- Lower Cost Processing, Fewer Rejections
- Higher Reliability at Equipment Wt
- Eliminate Pressure Ejection of Critical Nozzle Parts - Nozzle Attaches Directly to Composite Polar Boss

TR435

FIGURE 32

7-4-17-5 A3

Ballistic Missile Propulsion

Transition Targets....

- Small ICBM Design & Production
- Next Generation Ballistic Missile
- Future Missile Block Changes/Remanufactures
- All Aging & Surveillance Programs
- Forecast II
  - Long Range Air-to-Air Missile (PS-12)
  - Hypervelocity Weapons (PS-14)
  - Long Range Boost-Glide Vehicle (PS-18)
  - Advanced Heavylift Space Vehicle (PS-24)
  - High Temperature Materials (PT-17)
  - Advanced Manufacturing Technology (PT-30)

FIGURE 33

TR412

d. Funding

Table 4 shows the total funds to be expended in the Ballistic Missile Propulsion Technology thrust from FY 87 through FY 89. The following is an identification of the Program Elements supplying funds to this thrust:

11213F - Minuteman Squadrons
61101F - Laboratory Director's Independent Research Funds
61102F - AFOSR Research
62302F - Rocket Propulsion Exploratory Development
63302F - Space and Missile Rocket Propulsion Advanced Technology Dev
63311F - Advanced Strategic Missile Systems
64312F - Peacekeeper (MX)
64609F - Reliability and Maintainability Technology Insertion Program
65502F - Small Business Innovative Research
65807F - Test and Evaluation Support

e. Future Plans

Future work in the Ballistic Missile Propulsion Technology thrust will involve continued efforts to improve the performance and reliability of propulsion systems.

In the Service Life cluster future work (Figure 34) will concentrate on the understanding of propellant aging characteristics and on the development of nondestructive inspection techniques. Two specific efforts involved are studying high energy propellant/case interfacial bondlines and developing accept/reject criteria for the inspection techniques developed.

In the Advanced Booster Technology cluster future work (Figure 35) is planned for improving component material technologies which include ceramic composite polar bosses, high temperature cases and fixed nozzle TVC concepts. Technologies for penetration aids, re-entry vehicle propulsion and high acceleration will be developed. Integrated Stage Concept technologies will continue to be pursued.

In the Nozzle and Exit Cone Technology cluster future work (Figure 36) is planned for fully developing processing and failure criteria for current and advanced construction carbon-carbon materials, implementing computer tomography inspection techniques including the development of accept/reject criteria, and exploring the application of ceramic-ceramic composites.

The AFAL Component Laboratory continues to grow and helps us to improve our in-house capabilities in the areas of carbon-carbon and case fabrication. Major goals of the Component Laboratory are to develop nonproprietary processing techniques, characterize advanced fibers and resins, develop material inspection techniques, and establish nozzle and case failure criteria.

TABLE 4, BALLISTIC MISSILE PROPULSION FUNDING

PROGRAM ELEMENT	FY 87	FY 88	FY 89
11213F	17	17	17
61101F	150		
61102F	358	462	484
62302F	2,488	2,101	2,272
63302F	500	1,000	1,500
63311F		1,000	1,000
64312F	772	504	150
64609F	2,635	1,595	250
65502F	596	875	500
65807F	50	250	250

6-4-25-1 A8

Ballistic Missile Service Life....

TECHNOLOGY PROGRAM PLAN FY87-92

- Identify, Measure and Predict Manufacturing Variables Affecting Initial and Aging Characteristics of Solid Rocket Motors
- Develop Technology for Cost Effective and Comprehensive Surveillance Programs
- Understand Processes at High Energy Propellant/Case Interfacial Bondlines to Reduce Development Time and Cost, and Increase Reliability
- Develop Quantitative Nondestructive Evaluation Criteria/ Procedures for Accept/Reject of Solid Rocket Motors
- Identify, Measure and Predict Effect of Propellant Strain and Structural Properties on Ballistic Performance

TR415

FIGURE 34

7-4-17-5 A15

Ballistic Missiles

Advanced Booster Technology....

TECHNOLOGY PROGRAM PLAN FY87-92

- Component Material Technologies
  - Hot-Running Ceramic Composite Polar Bosses
  - Tough, High Temperature Cases
  - Fixed Nozzle TVC Concepts
- Penetration Aids & Reentry Vehicle Propulsion Technologies
- Integrated Stage Technologies
- High-Acceleration Technologies

FIGURE 35

TR429

7-4-17-5 A21

Ballistic Missiles

Nozzle and Exit Cone Technology....

TECHNOLOGY PROGRAM PLAN FY87-92

- Processing and Failure Criteria for Current and Advanced Construction Carbon-Carbons
  - 2D C-C Involute Construction
  - 3D Fine Weave Novoltex Construction
- Explore Ceramic-Ceramic Composites for Replacement of Nozzle's Weak Link: Degrading Thermal Insulators
- Imlement Use of Advanced Inspection Techniques for Nozzles
  - Bridge Inspection Data and Structural Analysis
  - Verify Defect Effects and Signatures
  - Process and Analyze Data Images
  - Basis for Accept-Reject Criteria on Future Nozzles

TR437

FIGURE 36

5. Multiple Application Rocket Propulsion Technology

This technical thrust is the germination bed of design and evaluation techniques that decrease development risks and life cycle costs, increase the design reliability of rocket propulsion systems, minimize the impact on the environment of rocket propellants and ingredients, and evaluate the feasibility of advanced concepts for rocket propulsion. This thrust is illustrated and summarized in Figures 37 through 46.

a. Objectives

The Multiple Applications Rocket Propulsion Technology major thrust highlighted in Figure 37 contains five clusters to provide enabling technology to the laboratory major thrusts for ballistic, tactical, and space propulsion advancement. The five clusters are Propellant Fundamentals, Improved Solid Propellants, Combustion Technology, Motor Structural Integrity, and Applied Research in Energy Storage. This thrust provides the core technologies that serve as the building blocks for propulsion advancements. The thrust provides feasibility demonstration of energy storage concepts, new ingredients, low cost processing methodology, improved safety concepts, motor structural integrity methodology, and means to improve performance and prevent combustion related problems in Air Force systems.

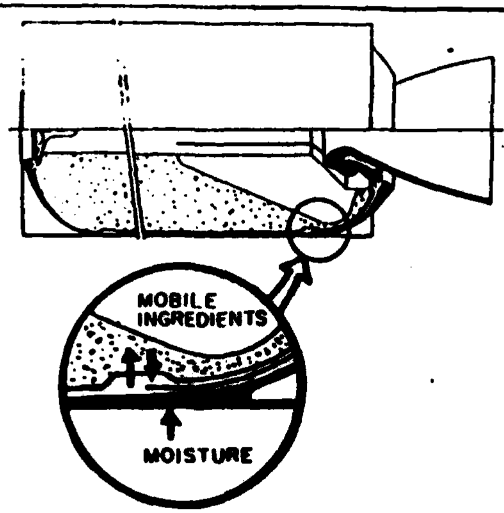
Advances in this thrust may be incremental, providing a broad base of research and applied technology that contributes to the solution of existing problems, or providing step function improvements and even technology breakthroughs. This thrust uses knowledge from the fundamental physical sciences to generate engineering problem solving tools. The application of two or more small technology advances can result in a large improvement in system capability. The energy storage cluster is evaluating the feasibility of radically new concepts which show potential for quantum improvements in propulsion capability. Emphasis is on applied research concepts highlighted in AFSC Forecast II deliberations. Innovative means to store energy in atoms and molecules and fundamental antimatter research are receiving primary attention. Improved propellants will emphasize low cost ingredients and processing techniques to reduce the cost of propulsion while maintaining or increasing performance capability. Thermoplastic elastomers, TPE, show promise for low cost propellant applications. Life cycle costs can be reduced by carefully developing new components to eliminate costly processing steps and identifying the life limiting design weakest link. Bonded interface improvements will be stressed. All clusters emphasize working with peers in other organizations to eliminate duplication and build upon technology advances. Transition of know how from this thrust to Air Force systems is the ultimate payoff.

b. Clusters

The clusters shown in Figure 37 will be discussed. Propellant fundamentals and improved solid propellants will be discussed as one technology subject.

6-4-25-1 D2

Multiple Applications Technology....



OBJECTIVE

- Advance State-of-the-Art in Core Technologies Applicable to All Rockets

CLUSTERS

- Propellant Fundamentals
- Improved Solid Propellants
- Combustion Technology
- Motor Structural Integrity
- Applied Research in Energy Storage

PAYOFFS

- Low Life Cycle Costs
- High Performance
- Reliable and Maintainable
- Revolutionary System Capability

TR084

FIGURE 37

(1) Improved Solid Propellants

This cluster is summarized in Figure 38. As the name implies, the purpose of this cluster is to develop the technology base for improving the properties of solid propellants. The fundamental chemistry effort ranges from synthesis and molecular tailoring research for improved ballistic properties to polymer separation methodology with the goal of improved binder stability and properties.

As a result of the need for low-cost access to space, major new emphasis is being placed on low-cost propellant ingredients, such as ammonium nitrate (AN) oxidizer and low-cost/continuous processing techniques. The development and use of AN as a propellant oxidizer in place of the currently used ammonium perchlorate oxidizer could reduce the cost of solid propellants by as much as $0.50 per pound. Work in this area is directed toward increasing energy and improving the combustion efficiency of AN propellants and investigating novel propellant processing methods including extrusion, emulsion, solution and dry blend/melt. Not only do all of these methods have the potential to reduce processing costs but they also enable the use of many energetic and low-cost ingredients not previously usable.

Development of thermoplastic elastomers (TPE) for use as solid propellant binders may be critical to the development of novel low-cost propellants/propellant processing techniques for space transportation. Therefore, major new in-house and contractual efforts are being initiated to develop TPE-based propellants. The TPEs are unique binders that do not chemically (irreversibly) cure, but cure by physical association of the polymer chains at ambient temperature. This process is reversible at elevated processing temperatures where the polymer chains dissociate, resulting in binder (propellant) melting. The other distinct advantages over current chemically cured propellants include indefinite pot-life and tailorability, reproducible mechanical and ballistic properties, low cost, and applicability to large-scale continuous propellant production. Initial feasibility studies have demonstrated that acceptable propellant mechanical properties can be achieved using low-cost, commercially available TPEs. Small scale rocket motors containing TPE based propellants have been fired.

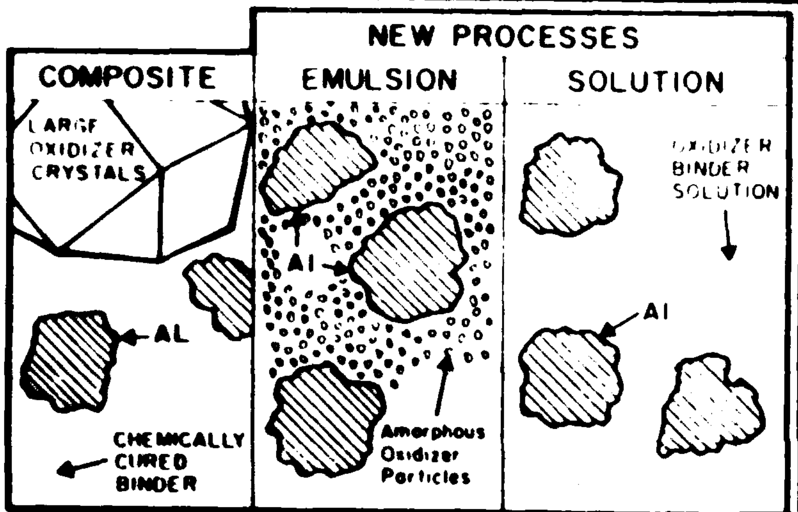
Efforts are continuing with glycidyl azide polymer (GAP), which is a low hazards energetic binder that offers unique improvements to propellant performance and ballistic characteristics. This unique combination of low hazards and improved performance makes GAP the most likely binder candidate for Class 1.3 minimum smoke and high burn rate propellant applications. In-house programs have demonstrated that "clean" burning GAP/AN/Al propellants can meet or exceed the theoretical performance of current AP propellants. Current and future programs will finalize GAP modifications and characterization techniques that will lead to the operational use of GAP in the near future.

(2) Combustion

This cluster is summarized in Figure 39. The long term goal of this cluster is to predict and improve motor/engine performance and stability; control ballistics and reduce development risks. For the past 10-15 years, the emphasis has

Multiple Applications

Improved Solid Propellants....



OBJECTIVES/GOALS

- Devc!op Low-Cost Ingredients/ Processing
- Identify and Reduce Hazards
- Demonstrate Reliability and Performance of Energetic and Low Cost Ingredients

TECHNOLOGY/CHALLENGES

- Thermoplastic Elastomer Propellant Development and Processing
- Efficient Low-Cost Ingredients
- Demonstrate Novel Processess
- Handling Hazardous Ingredients/ Propellants
- Improved Gap Aging and Characterization

PAYOFFS/MILITARY SIGNIFICANCE

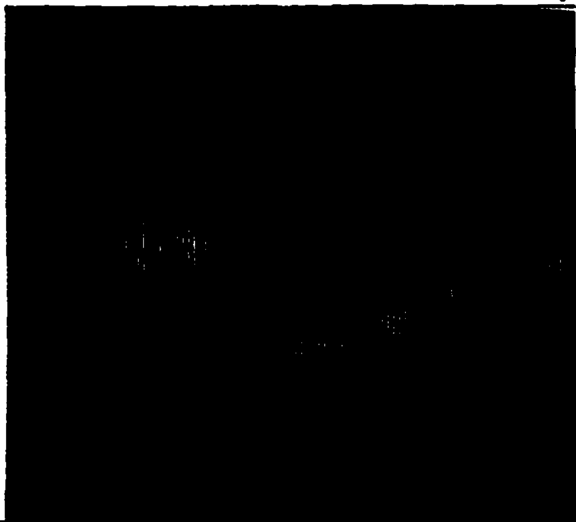
- Low-Cost Space Transportation
- Safe, Energetic, High Burn Rate Propellants
- Extended Service Life and Space Storability

FIGURE 38

TR499

G-4-25-1 D22

Multiple Applications
Combustion....



TECHNOLOGY/CHALLENGES

- Low-Cost, Reliable, Predictive Tools
- Control Complex, 3-D Rocket Motor Flow
- Constrain Temperature Sensitivity
- Provide Accurate Propellant Ballistics
- Predict High Area Ratio Nozzle Performance

OBJECTIVES/GOALS

- Predict/Prevent/Solve Instability
- Improve Propulsion Performance
- Eliminate Flow-Induced Problems

PAYOFF/MILITARY SIGNIFICANCE

- Increased Reliability
- Increased Range/Payload
  - $\Delta \pi_k$ of 0.03 = 1 sec of Isp
- Reduced Life Cycle Cost

TR508

FIGURE 39

been on solid rocket motors with the funding being split about 2 to 1 in favor of solids. Over the next few years, this ratio will be completely reversed, until 1993 when it will become approximately 50/50. This is being done to respond to the increased interest in liquids for use in space.

In the Solid Stability subcluster, several programs ending in FY 90 will better define how the propellant responds to the acoustic energy generated within a rocket motor. This coupling of propellant response with acoustic energy can lead to instability if not controlled. These programs will lead to better control of motor instabilities. The AFAL portion of a TTCP effort to validate a nonlinear methodology will also end in FY 90. This new technology, when validated, should reduce if not eliminate costly nonlinear instability problems. No further work in the Solid Stability area is planned until after FY 93.

The Solid Performance subcluster is also drawing to a close. A significant joint effort with BMO will have determined the SICBM head end insulation erosion rate and developed a model by the end of FY 90. Future work dealing with advanced motor performance models and ballistics will not be undertaken until after FY 93.

The Solid Motor Behavior subcluster includes programs that will determine ways to decrease the temperature sensitivity of solid propellants and improve the combustion efficiency of ammonium nitrate propellants, both of which are important to developing low cost, non-toxic heavy lift vehicles. Finally, two efforts that will start in FY 90 and FY 92, respectively, will develop ways to eliminate the nutation that has plagued some satellites during orbit transfer and examine the effects of very high pressure on solid *propellant combustion.*

The Liquid Stability subcluster will develop a significantly improved liquid stability model based on the mechanisms that are uncovered in an effort beginning in FY 89. Several programs in this area that will end in FY 89 will determine the mechanisms of energy absorption in liquid engine acoustic cavities and attempt to model them. Another program will develop an adaptive feedback method to adjust the performance of an acoustic cavity to the particular instability frequency being experienced.

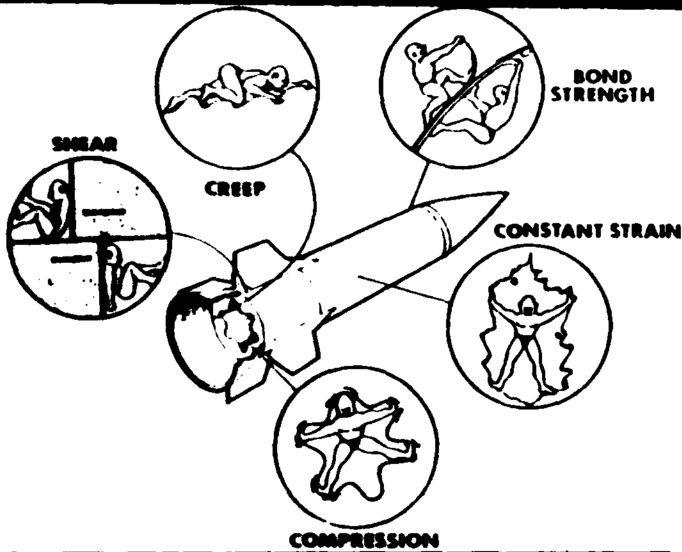
The Liquid Performance subcluster will develop a new performance model that will incorporate large area ratio nozzles as well as nonconventional ones. Liquid engines of the future will be operating at higher area ratios than they have in the past and the data available shows that we cannot predict the performance will at these area ratios where the boundary layers become the most significant unknown.

(3) Motor Structural Integrity

This cluster is summarized in Figure 40. This cluster develops technology required to assure the structural integrity and service life of solid rocket motors. Seven subclusters address specific areas within this broad charter. The Structural Analysis subcluster has produced advances in linear finite element analysis codes for solid rocket motors, and effort continues on the improvement, distribution, and maintenance of the improved linear codes, TEXGAP-2D and TEXGAP-3D. The major emphasis in this subcluster, however, is now on non-linear

6-4-25-1 D38

Multiple Applications
Motor Structural Integrity....



OBJECTIVES/GOALS

- Reliably Predict/Determine Motor Structural Integrity and Service Life
- Understand and Improve Bonded Interface Technology
- Understand Chemical Aging and Develop Failure Criteria
- Develop Reliable Non-Destructive Evaluation Technology

TECHNOLOGY/CHALLENGES

- Propellant "Realities" Still Exceed Analysis Capabilities
- Aging Interactions Not Understood
- Bondline is Most Complex Part of Motor

PAYOFFS/MILITARY SIGNIFICANCE

- Increased System Reliability—"Build it Right the First Time"
- Increased Service Life
- Problem Solving Support to SPO's and AFLC
- Increased Confidence in Solid Rocket Motor Launches

TR521

FIGURE 40

analysis technology. The major remaining problem is material non-linearity, and an intensive attack on this problem has begun. An additional goal in this subcluster is the strengthening and maintenance of AFAL's capability to perform in-house structural analysis of rocket motors and space structures. The Consolidated Analysis Code for Space Applications program (planned for FY 89) will give AFAL state-of-the-art analysis capability in the area of large solid rocket boosters and space structures.

The primary ongoing effort in the Failure Criteria subcluster is research on propellant fracture, with emphasis on the effects of strain fields and property gradients. This research will feed into work being done to develop structural analysis codes based on propellant microstructure and an effort to develop a unified propellant failure theory (starting in FY 91). Research on the failure characteristics of thermoplastic elastomers will also be conducted under this subcluster.

The efforts in the Experimental Structural Evaluation subcluster are aimed at resolving problems in propellant surface strain measurement. This technology is needed to evaluate analysis techniques as well as to directly evaluate motor structural integrity.

The Material Properties subcluster provides the experimental efforts which maintain the AFAL's in-house capability to evaluate propellant mechanical properties. Current efforts include characterizing the sensitivity of propellants to electrostatic discharge.

An effort in the Manufacturing Variables subcluster to provide methods for reliably obtaining structural benefits from curing motors under pressure is planned for FY 92.

The Bonded Interface Technology subcluster is the most heavily emphasized in the cluster. The goals are to understand and control the structural integrity and service life problems related to the motor interfaces: propellant/liner, liner/insulator, and insulator/case. One of the efforts is aimed at developing a computer code which will predict the migration and chemical reaction of mobile ingredients within a rocket motor, and to determine the resulting material properties for input to structural and service life analysis. Another effort will demonstrate the effectiveness of "insuliners" in solid rocket motors. The insuliner replaces the insulation and liner with a single material. This reduces the number of interfaces and greatly increases the reliability of the propellant grain through decreased complexity and fewer migrating ingredients. The AFAL is also establishing an in-house capability in this area.

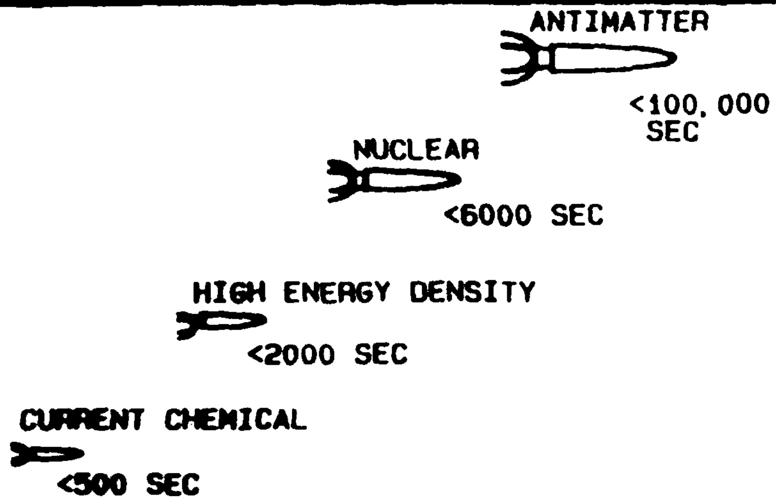
A new subcluster for this cluster is Nondestructive Evaluation (NDE). The programs in this area are aimed at developing an ultrasonic NDE device for the field inspection of tactical missile motors and at advancing the state-of-the-art for NDE of ballistic and space motors.

(4) <u>Applied Research in Energy Storage</u>

This cluster is summarized in Figure 41. The long term thrust of the High Energy Density Matter technology area is to create, stabilize, characterize

Multiple Applications

Applied Research in Energy Storage....



OBJECTIVES/GOALS

- Exceed Current Chemical Limitations
- Identify, Create, Stabilize and Characterize Candidate Substances
- Demonstrate Antimatter Enabling Technologies

TECHNOLOGY/CHALLENGES

- Accurate Theoretical Predictions
- Stability and Energy Density
- Cost-Effective Production Collection, and Storage of Antimatter
- Application Designs

PAYOFFS/MILITARY SIGNIFICANCE

- Increase Payload per Mission
- Allow Single Stage to Orbit
- Enable New Missions

TR531

FIGURE 41

and develop engineering designs for high energy density matter for potential use as propellants, fuels, and explosives. During the 1960's, there was much interest in exploiting such high energy species as metastables and free radicals. Unfortunately, the necessary computational and diagnostic capabilities were not available and most of the work ceased. With the advent of super computers, the computational problems are solvable now. With the tremendous advances in laser technology, not only are extremely fast selective, and sensitive diagnostics available but also the knowledge of metastables in laser plasmas gives insight that was previously lacking. These advances, along with new chemical bonding theories, have generated a renewed interest in the area of high energy density matter.

Current emphasis in this area is on theoretical and experimental studies to identify candidate materials possessing very high energy densities and to identify decay mechanisms and possible stabilization techniques. The greatest technical challenge will be to stabilize the products. The stabilization efforts will parallel the creation efforts. There will be constant feedback among identification, creation and stabilization efforts. As stable products become available, they will move into characterization efforts to determine physical and chemical properties. Since there is a high likelihood of some of the end products being different than current propulsion systems, conceptual engineering studies will be needed to determine how to best use the available energy.

Antimatter represents the highest possible energy storage density known to science. Microscopic amounts of antimatter could in principal be used to heat propellants to arbitrarily high exhaust velocities, enabling rockets for existing missions to be much smaller, permitting new high velocity missions. Currently, antimatter must be made in high energy "atom smashers" at very great expense and at rates too small for practical use. It yields its energy whenever it is allowed to come in contact with normal matter, and thus must be kept in a near perfect vacuum, suspended by electrostatic or magnetic fields. AFAL has initiated an assessment program with Rand Corporation to determine whether antimatter can eventually be produced, stored and used in the quantities needed for propulsion at a reasonable price.

The most convenient way to store antiprotons would be to combine them with anti-electrons (positrons) to make antihydrogen ice or to form hydrogen cluster ions. AFAL has initiated a project to investigate technology for making hydrogen cluster ions. These methods would then be used for antihydrogen. Research into technologies capable of handling the plasma exhausts created by mixing matter and antimatter could be used for other, nearer term concepts. Thus, research was funded by AFAL at Lawrence Livermore Laboratory on matter-antimatter reactions, and work is in progress on magnetic nozzles which contain a plasma exhaust with an applied magnetic field. The Rand assessment includes input from national experts in all of the technologies required to take antimatter from production to application. This assessment will form the basis for AFAL plans in the area.

c. Payoffs

Figures 37, 38, 39, 40 and 41 show some of the payoffs that can be realized through development of multiple application propulsion technology. New, better, and cheaper ways to provide more reliable rocket propulsion best describes the payoff of this thrust. The programs in this thrust provide the basic ground work from which our understanding of rocket propulsion evolves; these are our "core technologies." The understanding derived from this thrust allows us to investigate innovative higher energy density concepts, to develop improved propellants for increased rocket performance, and to provide low risk, low cost propulsion concepts and approaches. Efforts are under way that promise to reduce propellant processing costs. Ballistic modification to reduce the propellant temperature sensitivity can provide the equivalent of several seconds of Isp when used to optimize rocket motor design parameters. Improved knowledge of bonded interface phenomena will result in higher performance and greater reliability for Air Force missiles.

Figure 42 identifies the Multiple Applications Technology thrust transition targets. Transition to the applications thrusts is the significant output of technology from this thrust. We seek energetic, chemically stable and safe propellants. The combustion process must be stable and efficient. Improved design tools are needed for structural and combustion analyses. Advanced concepts for potential high energy density materials and antimatter research are needed to meet the requirements of AFSC Project FORECAST II. The concepts are high risk, but have very high payoff potential. In a generic sense, all improvements must be made without compromising logistics requirements. We seek before the fact improvements and after the fact solutions.

d. <u>Funding</u>

Table 5 shows the funding we plan to apply to this thrust. The Program Element 61101F monies are from the Laboratory Director's Independent Research Fund. The 61102F monies are AFOSR research funds being applied to rocket propulsion goals. The exploratory development investigations are accomplished under Program Element 62302F, Project 5730.

e. <u>Future Plans</u>

Figures 43 - 46 identify the project emphasis in this thrust. They are presented in the general order according to the cluster responsible for the work.

<u>ORGANIZATION</u>

AFAL organizational chart as of October 1987 is shown in Figure 47.

<u>FACILITIES</u>

AFAL facilities are shown pictorially in Figure [illegible].

6-4-25-1 D4

Multiple Applications Technology

Transition Targets....

- Applications Thrust
  - Low Cost, Energetic, Safe Propellants
  - Stable Combustion, High Efficiency
  - Improved Design Tools (Liquids and Solids)
- Logistics R&D
  - Before the Fact Improvements
  - After the Fact Solutions
- Forecast II
  - High Energy Density Propellant (PT-1)
  - Antimatter Propulsion (PT-42)
  - Active/Passive Broad Spectrum Signature Control (PT-18)
  - Long Range Air-to-Air Missiles (PS-12)
  - Advanced Heavy Lift Space Vehicle (PS-24)
  - Space-based Reusable Orbit Transfer Vehicle (PS-28)

FIGURE 42

TR086

TABLE 5, MULTIPLE APPLICATIONS PROPULSION TECHNOLOGY

($K)

PROGRAM ELEMENT	FY 87	FY 88	FY 89
61101F	677	-	-
61102F	1,319	1,670	1,870
62206F	-	125	200
62302F	5,975	6,510	6,895
64312F	494	300	300
64609F	-	200	600
SDI	2,640	1,710	864
65502F	350	200	-
78011F	-	-	1,200
NASA	198	-	-

7-4-17-5 D4

Multiple Applications

Improved Solid Propellants....

TECHNOLOGY PROGRAM PLAN
FY87-92

- Reproducibility of GAP Through Stabilization
- Safe High Performance Ingredients Through Encapsulation
- Advanced Processing Through On-Line Characterization
- Large Scale Low Cost Processing
- Thermoplastic Elastomer Motor Evaluation

FIGURE 43

TR503

7-4-17-5 D21

Multiple Applications

Combustion....

TECHNOLOGY PROGRAM PLAN FY87-92

- Solid Stability Technology
- Solid Performance Technology
- Solid Behavior Technology
- Liquid Stability Technology
- Liquid Performance Technology

FIGURE 44

TR513

6-4-25-1 D40

Multiple Applications

Motor Structural Integrity....

TECHNOLOGY PROGRAM PLAN FY87-92

- Develop New Technology for Improving Bonded Interfaces, Including Shear Stress Measurement
- Develop Advanced Nonlinear Structural Analysis Codes and Improve Present Codes
- Develop In-House R&D Methods for Evaluating Physical Properties of Solid Propellants
- Understand Chemical Interactions of Solid Propellant Ingredients during Aging Process
- Identify Causes/Effects of Failure in Solid Rocket Propellant
- Develop Capability to Predict NDE Failures
- Understand Manufacturing Variable Effects on Motor Structural Integrity

FIGURE 45

TR519

Multiple Applications

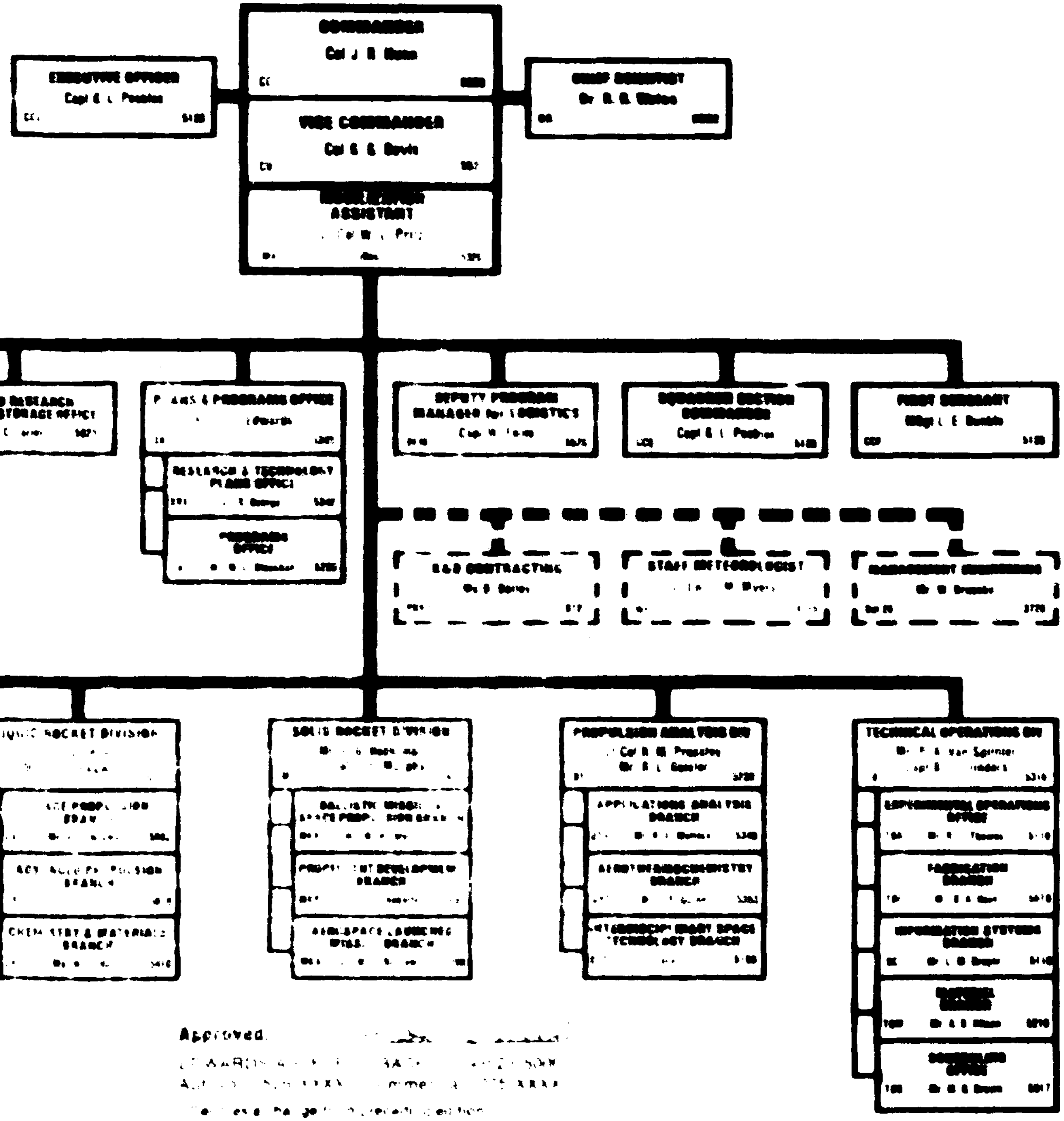
Applied Research In Energy Storage....

TECHNOLOGY PROGRAM PLAN FY87-92

- High Energy Density Matter
  - New Bonding Theories
  - Theoretical Screening/Surveys
  - Experimental Verification/Characterization
  - Feasibility/Stabilization
- Antimatter
  - Antimatter Technology Base
  - Dense Storage

Air Force Astronautics Laboratory

as of 1 October 1987



AIR FORCE ROCKET PROPULSION LABORATORY FACILITIES....

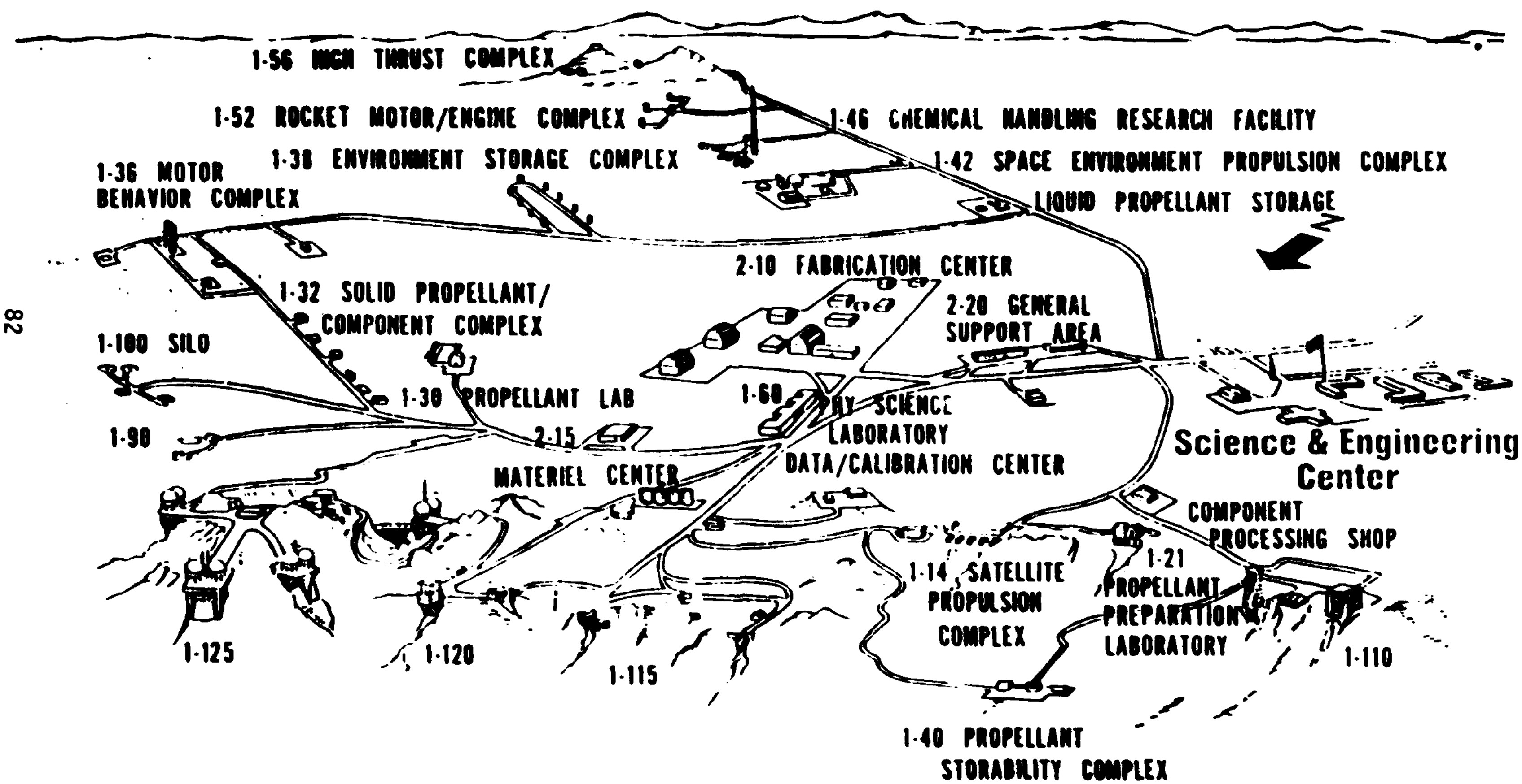


FIGURE 48

APPENDIX

FY 88 & 89 COMPETITIVE PROGRAM LISTING

Notes:

1. This list contains those programs we expect to award to industry competitively.

2. The program work units are organized by Technical Thrust.

3. This program list was prepared as a "slice in time" and is subject to changes.

FY 88 SPACE SYSTEMS PROPULSION PLANNED NEW STARTS

TITLE: Breadboard XLR-132 Performance Demonstration

Performance Period: Mar 88-Sep 88

OBJECTIVE: Assess vacuum performance of the XLR-132. Conduct in-house evaluation of the breadboard XLR-132 engine assembly under simulated altitude conditions. Experimental results will be compared with analysis to provide design guidance for reusable configuration.

TITLE: CVD Coating Technology Demonstration

Performance Period: Jan 88-Aug 89

OBJECTIVE: Demonstrate the feasibility of coating engine components by chemical vapor deposition with high temperature, oxidation resistant coatings and assess their protection potential. Simulated engine components will be CVD coated optimizing deposition temperature, CVD chamber shape and deposition gas flow. These components will be subjected to simulated engine environment to assess the degree of protection provided.

TITLE: OTV Issues

Performance Period: Apr 88-Jul 89

OBJECTIVE: Evaluate critical issues of performance, thrust level, and reliability for application of the XLR-132 to future space propulsion systems. Trade-off studies and analyses will be conducted based upon inputs from Space Division's Adaptable Space Propulsion System study.

TITLE: Safe Cryo Design

Performance Period: Apr 88-Jul 89

OBJECTIVE: Identify and evaluate the propulsion technology required for a safe cryogenic shuttle-based orbit transfer vehicle. Utilizing the design information from the Compact Cryo Feed System Demonstration program and the safety study results of the Shuttle Centaur program, conduct analyses and trade-off studies to identify the propulsion technology requirements necessary to support a safe cryo OTV.

TITLE: Improved Propulsion Reliability Study

Performance Period: Mar 88-Feb 89

OBJECTIVE: Identify technology investment areas and strategies for improved launch vehicle propulsion reliabiliy. Conduct analyses and trade-off studies to provide alternative approaches to statistical testing and/or apportionment of reliability for launch systems where the cost of unreliability is very high as well as the cost of conducting statistical testing.

FY 88 INTERDISCIPLINARY SPACE TECHNOLOGY PLANNED NEW STARTS

TITLE: Embedded Sensor/Actuator Development

Performance Period: Jan 88-Sep 91

OBJECTIVE: Identify vibration and shape control needs of large space system configurations and predict the performance of embedded sensors and actuators in those applications. Specific systems will be studied to determine their vibration and shape control needs. Parametric studies will be conducted to determine how embedded sensors and actuators can handle system control problems.

TITLE: Have Tenacity

Performance Period: Jul 88-Sep 90

OBJECTIVE: Establish the feasibility and applicability of new techniques to DSAT applications. Analysis and bench scale testing will be utilized to assess the potential effectiveness of techniques previously identified.

TITLE: Spacecraft Analysis Model

Performance Period: Jan 88-Aug 90

OBJECTIVE: Develop a spacecraft preliminary design tool to perform technology trade studies. Existing models will be studied to determine their capabilities, ease of use, hardware requirements, accuracy, cost and computer time required. A model will be modified or developed to meet the overall requirements established.

TITLE: Space Heat Exchanger Ground Demonstration

Performance Period: Jul 88-Aug 90

OBJECTIVE: Demonstrate the operation of a direct contact heat exchanger in a simulated space environment. Analyses will be conducted to establish test operating conditions and test parameters. Alternate configurations will be studied prior to establishing the test article design. Performance data will be acquired under simulated space conditions and correlated to analytical predictions.

TITLE: Liquid Droplet Environmental Interactions

Performance Period: Jan 88-Mar 90

OBJECTIVE: Analytically and experimentally examine the interactions between the space environment and free liquid droplet streams of various materials. Investigations will be made of all aspects of the space environment that may have an impact on the feasibility of operating characteristics of a liquid droplet sheet in space. The environmental phenomena include atomic oxygen, solar radiation, upper atmospheric effects and micrometeoroids.

TITLE: Thermodynamic Vent System Components Demonstration

Performance Period: Jan 88-Sep 90

OBJECTIVE: Develop and demonstrate long life fluid control components and redundant configurations for liquid hydrogen thermodynamic vent systems to ensure long term operation in space. A trade study will be performed to identify design options which satisfy requirements for long term space storage of cryogenic systems. Reliability and potential failure modes will be assessed. Tests will be conducted to verify flow and pressure control and operating life.

TITLE: E. T. Contamination Diagnostics Application

Performance Period: Jan 88-Sep 90

OBJECTIVE: Characterize the flowfield properties of an actual electric thruster using previously developed techniques. Set up an electric thruster in a specially equipped simulated altitude chamber at Aerospace Corporation. Measure the flowfield properties at various aspect angles to the thruster axis. Provide the data to AFGL contamination data base.

TITLE: Solar Dynamic Space Power

Performance Period: Dec 8[illegible]-Sep 89

OBJECTIVE: Investigate methods to improve the reliability, efficiency, and life of solar dynamic space power systems. Analyses will be conducted of current concentrator, heat receiver and electrical generation system technologies directed at space power. An evaluation will be made of the applicability of high concentration ratio, inflatable mirror technology and heat receiver/engine combinations capable of accepting higher energy flux.

TITLE: Automated Management System

Performance Period: [illegible] 88-Jul 90

OBJECTIVE: Determine the cost and technical feasibility of implementing a totally automated (paperless) management system for space launch vehicle operations and manufacture. A survey of current management systems will be evaluated and a detailed cost and time history will be assembled. Current timelines for assembly and launch preparation of a typical space launch vehicle will be used as a baseline from which to measure the effect of implementing an automated management system. A system will be designed and traded-off against the cost of today's system.

TITLE: Application of Composites to Spacecraft Structures

Performance Period: Jan 88-Sep 90

OBJECTIVE: Define and evaluate the application of composite structures to spacecraft. A survey will establish the requirements and materials best suited for spacecraft applications. Baseline designs will be developed to identify technology gaps. Selected sub-scale composite structures will be fabricated and evaluated in AFAL facilities to establish additional technology development requirements.

TITLE: Advanced Composites with Embedded Sensors and Actuators

Performance Period: Dec 87-Sep 91

OBJECTIVE: Design, fabricate and evaluate composite structs and panels with embedded sensors, actuators and microprocessors. Based upon previous programs, analyses will be conducted to establish a design approach for selected spacecraft components utilizing composite structures with embedded control functions. Sub-scale and selected full-scale investigations of the fabrication process and evaluation of the control functions will be conducted at AFAL.

TITLE: Coatings/Adhesives for Space Environment

Performance Period: Feb 88-Feb 92

OBJECTIVE: Identify space environment issues and in-orbit repair senarios and develop rational material selection criteria for polymers to meet the defined needs in space. Performance improvement and maintainability issues will be identified for anticipated space structure designs. Evaluations will be conducted of the effect of the space environment on coatings and adhesives establishing fundamental relationships. Space-specific material test methods will be developed.

TITLE: Composite Structure for Payload Shrouds

Performance Period: Dec 87-Sep 88

OBJECTIVE: Determine techniques for application of advanced composite materials to space and ballistic missile payload shrouds for reduced weight and cost. Analyses will be conducted to identify the potential weight and cost savings achievable by employing composite structures. Initial designs will be developed and assessed.

TITLE: Thin Film Structures

Performance Period: Mar 88-Mar 89

OBJECTIVE: Analytically determine the feasibility and payoff of using thin film for structural members in space. Analyses will be conducted to establish thin film structural applications based upon previously established physical properties data. Feasibility and payoffs will be identified compared to more conventional techniques. Additional technology efforts required will be identified.

FY-88 AIR-LAUNCHED PROPULSION PLANNED NEW STARTS

TITLE: Plume Radar Cross Section Measurements

Performance Period: Jun 88 - Oct 90

OBJECTIVE: The measurements to be conducted in this program will determine the importance of the plume RCS for SPOs concerned with low observables. A secondary objective will be to assess the accuracy of the Navy (NWC) RCS plume prediction codes PRFIC and PARCS.

TITLE: High Pressure Nozzle

Performance Period: Mar 88 - Mar 91

OBJECTIVE: To design and demonstrate in flightweight hardware a rocket motor nozzle that can be used for motor operation above 1000 psi with a goal of 5000 psi. The nozzle must also be able to withstand pulse motor operation.

TITLE: Chemical-Structural Aging of Ammonium Nitrate Propellants

Performance Period: May 88 - Oct 91

OBJECTIVE: An aging program which includes thermal cycling in various humid environments will provide at least 12 months of accelerated aging data and 30 months of ambient aging data. Frequent (planned matrix) chemical, physical and mechanical properties will be conducted and related to typical motor structural parameters. Data will be used to predict the long term (20 years) aging characteristics of this class of propellants.

TITLE: Determination of Aircraft Missile Environment II (DAME II)

Performance Period: Apr 88 - Oct 91

OBJECTIVE: To determine the acoustic, thermal, and vibrational environments for missiles in the internal/external carriage of F-15E, B-1B, ATB, ATA, and ATF aircraft.

TITLE: Advanced Propulsion Study

Performance Period: Oct 87 - Sep 89

OBJECTIVE: Achieve a more complete understanding of advanced tactical propellants which are being considered for future air-launched missile applications. Identify future systems technology and perform trade-off analysis for any type of propulsion system that might be applicable to air-launched missiles scenerios.

FY 88 BALLISTIC MISSILE PROPULSION PLANNED NEW STARTS

TITLE: Ballistic Missile Manufacturing Variability

Performance Period: Mar 88-Jul 91

OBJECTIVE: Processing and manufacturing variables have not been investigated for their effect on the newer high energy Class 1.1 propellant as they affect service life and structural integrity. This program will define and quantify effects of processing and manufacturing that would have an impact on the aging process of the motor.

TITLE: High Acceleration Propulsion Definition Study

Performance Period: Jan 88-Jul 89

OBJECTIVE: This is an analytical effort to define propulsion technology research goals for high acceleration boosters and their post-boost vehicles.

TITLE: Carbon-Carbon (C-C) Basic Studies

Performance Period: Oct 87-Sep 93

OBJECTIVE: Processing failures of carbon-carbon (C-C) exit cones and nozzles demonstrate the lack of a thorough understanding of carbon materials and C-C processing techniques. Additionally, firing failures of rocket nozzle subsystems indicate a lack of basic material property data for use in design and analysis. This program will develop improved processing techniques and methods for two-directional (2D) C-C exit cones and nozzles. Also to study precursor materials and improve the cure, carbonization, graphitization, and densification cycles.

TITLE: Non-degrading Insulator Analysis

Performance Period: Mar 88-Sep 90

OBJECTIVE: This is an in-house analytical program to examine and perform advanced analyses on current and future nozzle designs with emphasis on defining requirements for nondegrading ceramic insulators.

TITLE: Implementation of CT Workstation

Performance Period: Apr 88-Sep 89

OBJECTIVE: This project will provide support equipment and services for the Remote Data Workstation to allow its capabilities to be fully exploited.

FY 88 MULTIPLE APPLICATIONS PROPULSION PLANNED NEW STARTS

TITLE: Solution-Cast Propellant Development and Casting

Performance Period: May 88 - Nov 90

OBJECTIVE: Requirements for space launches with advanced lift vehicles by SDI and DOD will generate a solid propellant need of over one billion pounds by the beginning of the 21st century. The projected annual solid propellant capability is aproximately 70 million pounds. Cost analyses indicate that propellant costs are nearly twenty percent of motor costs, and can be as high as thirty-percent for a reusable motor. A significant reduction in propellant costs is needed for practical space transportation costs to be realized. Solution-cast propellants offer a realistic approach for achieving low cost propellants with acid-free exhaust (clean or non-hydrochloric acid) at high productions rates without extensive energy and labor investments. The feasibility of solution-case propellants has been studied and the program results indicate that these propellants have the potential of meeting space launch needs. The program objectives are to have the potential of meeting space launch needs. The program objectives are to develop and demonstrate a solution-cast clean propellant or propellants [illegible] with continuous solid propellant manufacture that are suitable for [illegible] vehicle applications.

TITLE: Ultrasonic Nondestructive Evaluation for Solid Rocket Motors

Performance Period: Jul 88 - Jul 92

OBJECTIVE: Current NDE procedures for aging and surveillance [illegible] quality assurance of tactical solid rocket motors is costly, labor intensive, [illegible]. This program will develop a transportable ultrasonic inspection device for the field or depot level NDE of these motors. Such a device will eliminate the [illegible] to ship motors from the depot where they are stored to an x-ray facility. [illegible] sensitivities equal to x-ray. It is non-hazardous, inexpensive, and [illegible] technician level personnel. A prototype of this device will be delivered [illegible].

TITLE: Propellant/Case Interface Aging Interaction

Performance Period: Apr 88 - Apr 9[illegible]

OBJECTIVE: Current understanding of service-life limiting interactions between composite cases and propellant/case bond systems is limited. The objective of the program is to determine, understand, and control these interactions. The Air Force is moving more and more towards composite cased solid rocket motor systems for their missiles. A before-the-fact study in this area will allow the Air Force to reduce procurement and support costs for these missile systems.

TITLE: Gap Stabilization

Performance Period: Apr 88 - Sep 90

OBJECTIVE: Develop and demonstrate a stabilizer system for GAP propellants that provides protection equal to that achieved in HTPB propellants. Formulate GAP gumstocks with a wide variety of commercially available antioxidants and metal deactivators. Assess, by accelerated aging, their effect on GAP stability and establish possible degradation routes for the GAP backbone in different environments. Combine various stabilizers that show promise to evaluate synergistic effects. Select the best combinations of stabilizers and evaluate in solid propellant formulations. Evaluate each stabilizer package with respect to potlife, accelerated aging, and humidity.

TITLE: Rheol Char for Improved Prop Processing

Performance Period: Mar 88 - Sep 90

OBJECTIVE: Determine rheological measurements and properties which are relevant in characterizing propellant processing from the beginning of mixing to the completion of casting. Rheological measurements which relate to specific processing steps must be determined and the relevant rheological properties identified for all phases of propellant mixing. Formulation dependent constitutive models must be developed for all process conditions. The determined constitutive relationships must be used in the development of accept/reject criteria which ultimately provide quality assurance.

TITLE: Solid Propellant Flow Modeling

Performance Period: Nov 87 - Oct 89

OBJECTIVE: Determine the distribution of solid particle constituents during the processing of solid propellants. Three specific tasks must be performed: (1) Investigation of simple bimodal and trimodal systems under a range of flow situations to determine the parameters and conditions which lead to particle orientation; (2) Development of a theoretical model which incorporates all constituents of a composite solid propellant including up to four discrete particle size distributions. The model must account for the relevant interactions which lead to particle orientation, and must accurately predict orientation effects for the flow situations of interest; (3) Rheological characterization of sample propellants to provide input to both the experimental model system investigation and to the development of the theoretical computer code model.

FY 89 SPACE SYSTEMS PROPULSION PLANNED NEW STARTS

TITLE: Advanced Material Technology Components

Performance Period: Apr 89-Sep 93

OBJECTIVE: Demonstrate the advanced material and fabrication technology capable of reducing large liquid engine weight by forty percent. An engine design will be generated utilizing advanced lightweight materials for high temperature engine components. Selected components will be fabricated and subjected to stress and thermal loading to demonstrate their capability. Operation at actual engine conditions will be demonstrated on a technology demonstrator engine.

TITLE: Composite Materials Applications

Performance Period: Mar 88-Sep 90

OBJECTIVE: Fabricate lightweight components for launch vehicle applications from advanced composite materials and develop nondestructive evaluation techniques to verify their integrity. Results of previous studies on advanced composite materials will be used; components will be fabricated and tested in-house.

TITLE: Autonomous Monitoring for SRB

Performance Period: Mar 88-Sep 92

OBJECTIVE: Identify environmental and load monitoring equipment useful to solid rocket motor launch vehicles. Identify lightweight, low cost condition monitoring devices, determine the placement of critical monitoring equipment, perform cost vs weight vs [illegible] assessment, and conduct feasibility testing of candidate concepts.

TITLE: Automated SRM Fabrication Technology

Performance Period: Dec 88-Sep 92

OBJECTIVE: Investigate automated fabrication techniques for space launch vehicle solid rocket boosters. Automated fabrication techniques will be identified and refined based upon the previous SRM Design for Automation program. The most promising concepts will be evaluated in sub-scale hardware. Full-scale implementation cost, life cycle cost, and cost reduction potential will be developed.

TITLE: Reusable XLR-132 Technology

Performance Period: Jan 89-Aug 92

OBJECTIVE: Demonstrate the technology required to extend the life and provide health monitoring of the XLR-132 engine. Analyses will be conducted to establish the design modifications required to obtain a reusable engine configuration. Health monitoring, modularity and space operations will be evaluated. Cost effective technologies will be developed and incorporated into the XLR-132 engine design.

AD-A187 861 AFAL (AIR FORCE ASTRONAUTICS LABORATORY) TECHNICAL OBJECTIVE DOCUMENT FY89(U) AIR FORCE ASTRONAUTICS LAB EDWARDS AFB CA DEC 87 AFAL-TR-87-058

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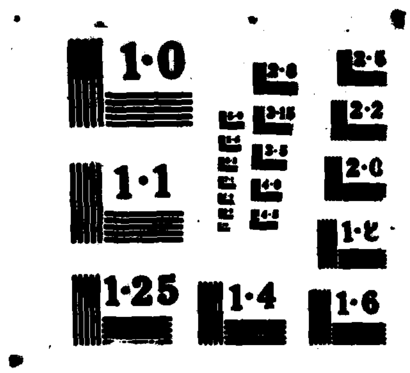
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TITLE: Integrated ACS Study

Performance Period: Mar 89-Sep 90

OBJECTIVE: Develop a technology plan for a high performance, extended life ACS thruster and feed system components for integration with a storable pump-fed orbit transfer and maneuvering primary propulsion system. Identify the critical components. Analyses will be conducted to define the most effective means for integrating the primary and ACS systems. The primary propulsion system will baseline the XLR-132 engine.

TITLE: Low Thrust Maneuver Engine Demonstration

Performance Period: Jan 89-Jan 92

OBJECTIVE: Design and demonstrate an advanced low thrust storable bipropellant propulsion system for satellite maneuvering. Inputs from system program offices and the Maneuvering Propulsion System study will be utilized to establish basic design and engine concept selection. Detailed design studies will be conducted followed by engine fabrication and evaluation to a representative duty cycle.

TITLE: LSS Thruster

Performance Period: Jun 89-Mar 91

OBJECTIVE: Identify reaction control system capabilities necessary to provide the required control authority for large space systems. Detailed studies and trade-off analyses will be conducted based upon the results of the Flexing Structure Space Systems Control program to identify and design critical reaction control system components.

TITLE: High Performance 100 lb_f Thruster

Performance Period: Dec 89-Jun 91

OBJECTIVE: Design and demonstrate a high performance 100 lbf storable rocket engine. A high temperature coating identified in a previous program will be applied to the gas side wall to allow higher temperature, therefore, higher performance operation. demonstration testing will be conducted to establish the performance increase realized.

TITLE: XLR-134 Life Evaluation

Performance Period: Oct 89-Sep 93

OBJECTIVE: Demonstrate the durability and delivered specific impulse of a low thrust, high area ratio, expander cycle LO_2/LH_2 engine. The XLR-134 breadboard engine assembly previously fabricated and tested under contract will be installed in the AFAL Experimental Area 1-14, instrumented, and operated over a range of mixture ratios to independently determine the altitude delivered performance. The engine will be operated for at least ten house to verify the durability of the engine and provide critical wear data for reusable XLR-134 technology.

TITLE: Small Turbopump Technology

Performance Period: May 89-Sep 92

OBJECTIVE: Demonstrate advanced turbopump technologies through extensive life testing. Baseline low thrust hydrogen/oxygen turbopump designs will be developed incorporating advanced technology components in such areas as tearings, flow passages, seals and health monitoring. Bench tests will be conducted over several mission life times. Successful designs will be incorporated into a breadboard turbopump and demonstrated.

TITLE: Low Cost EEC System

Performance Period: Jan 88-Sep 90

OBJECTIVE: Develop a low cost EEC deployment system for solid rocket space motors. Flight-type systems, using the IUS as a baseline, will be bench-tested and their performance, weight and overall system complexity compared to current systems. A final design will be built and tested which meets all performance requirements at a greater to or equal reliability as IUS at a significantly reduced cost.

TITLE: Improved Gas Deployment Skirt

Performance Period: Jan 89-Sep 92

OBJECTIVE: Demonstrate the increase in Isp possible by using very high expansion ratio gas deployed skirts. Conduct material characterization tests on columbium alloys and high temperature resistant organic polymer films. Perform analyses to identify the highest expansion ratio per unit skirt weight and conduct cold flow, hot firings.

TITLE: EM Signature Model

Performance Period: Jan 89-Sep 91

OBJECTIVE: Develop a model to determine the origins of EM emissions from the rocket exhaust plume. Current theories will be reviewed based on their plausibility in light of recent measurements. Modifications will be formulated based on inconsistencies found and embedded in a model to predict EM emissions. A test plan of experimental measurements needed to verify the model will be prepared.

TITLE: EM Signature Measurements

Performance Period: Jan 89-Dec 93

OBJECTIVE: Experimentally determine the origins of EM emissions from rocket exhaust plumes. A series of 70 lbm BATES motors will be fired according to the test plan developed in the EM Signature Model program. Propellant formualtions will be varied to test different theories. EM monitoring equipment will be used to determine propagation and attenuation effects.

TITLE: Advanced Nuclear Propulsion

Performance Period: Jan 89-Sep 92

OBJECTIVE: Evaluate advanced nuclear fission propulsion systems, determine their feasibility, and address the means by which to solve the technical issues inherent to each concept. The analyses will concentrate on high power density, efficient, safe propulsion reactor concepts capable of achieving 1500 sec of Isp.

TITLE: Baseline 30KW - Class Arcjet ATD

Performance Period: Apr 89-Sep 92

OBJECTIVE: Develop and demonstrate a prototype 30KW arcjet propulsion system consisting of thruser, power conditioning, propellant feed and thermal management subsystems. Subsystem development will be followed by integration and performance evaluation under simulated altitude conditions. Life test and qualification for a space test program ill be conducted.

TITLE: Solar Engine Life Test

Performance Period: Dec 88-Sep 92

OBJECTIVE: Develop and demonstrate a flight-configured 10 lbf thrust class solar rocket engine. Design analyses will be conducted based upon the outcome of previous low thrust solar rocket programs. Design verification tests will be conducted of critical components. A full-scale engine will be fabricated and subjected to a life-test evaluation.

TITLE: Fusion System Analysis

Performance Period: Jan 88-Sep 89

OBJECTIVE: Define and evaluate potential fusion propulsion system concepts capable of delivering high thrust at Isp from 1,500 to 10,000 sec. System concepts will be defined based upon the Fusion Propulsion Study program results. System components will be defined and weights and performance values calculated. Technology needs will be identified.

FY 89 INTERDISCIPLINARY SPACE TECHNOLOGY PLANNED NEW STARTS

TITLE: Space Deployment Targets of Opportunity

Performance period: Sep 89-Feb 93

OBJECTIVE: Obtain on-orbit deployment data from a host satellite during its deployment sequence. Spacecraft in the Space Test Program will be reviewed for deployment requirements. One will be selected and its deployment dynamics predicted prior to launch. The spacecraft will be instrumented to obtain the actual data. The prediction codes will be upgraded as required, based upon post-flight analyses.

TITLE: Spacecraft System Identification

Performance Period: Dec 88-Jun 91

OBJECTIVE: Develop and demonstrate system identification techniques for identification of the structural model of precision structures. Analyses will be conducted to establish an overall method for identification and control of large space systems and parameter estimation techniques. Demonstrations will be conducted on test structures at the AFAL.

TITLE: On-Orbit System Identification

Performance Period: Dec 88-Mar 92

OBJECTIVE: Develop system identification techniques for on-orbit identification of the structural model of precision structures. Analyses will be conducted to provide an overall method utilizing a minimum number of sensors and actuators for identification and control of large space systems. Parameter estimation techniques identified in prior programs will be evaluated for their applicability. A demonstration will be conducted on a realistic LSS.

TITLE: Liquid Droplet Radiator Concept Enhancement

Performance Period: Mar 89-Mar 91

OBJECTIVE: Investigate techniques for improving liquid droplet generation and collection in space. Analysis and experiments will be conducted based upon data from previous liquid droplet radiator projects. The experiments will include examining different approaches to enhance both droplet generation and collection.

FY 89 AIR-LAUNCHED PROPULSION PLANNED NEW STARTS

TITLE: 1.3 Minimum Smoke Propellant Demonstration

Performance Peirod: Oct 88 - Jan 91

OBJECTIVE: Using formulations of Class 1.3 minimum smoke propellant, the latest known information will be used to improve the propellant which through preliminary testing is found to be most promising. The final formulation will be scaled through to a 600 (nominal) gallon mix level. A thorough ballistic (BATES motors), mechanical, and hazards evaluation will be conducted. The propellant must satisfactorily perform from -65° to +145°F.

TITLE: Aero-Configured Motor Demonstration

Performance Period: Mar 89 - Sep 91

OBJECTIVE: To capitalize on the results of the "Non-Symmetrical Motor Case" program previously conducted and design, fabricate, and test a rocket motor in an aero-configured shape; demonstrate motor structural integrity, and ballistic conformity to air-launched environments.

TITLE: Advanced Air-Launched Propulsion Concept Feasibility

Performance Period: Mar 89 - Jul 91

OBJECTIVE: Review the results of the "Advanced Propulsion Study" contract. Select key component technologies for risk reduction. Design, fabricate and test heavyweight components to demonstrate the feasibility of the most promising propulsion concepts.

TITLE: Composite Sizing Evaluation

Performance Period: Dec 88 - Jul 91

OBJECTIVE: To identify and quantify the effects of surface finishes on fibers and to identify and quantify compatibility of fiber finishes with various resins. Evaluate fibers for chemical and mechanical damage; evaluate the actual phenomena of bonding various classes of resins to the different fibers with and without finishes.

TITLE: Low Cost Evaluation Motor

Performance Period: Jun 89 - Jun 93

OBJECTIVE: To investigate areas where manufacturing may be modernized and costs reduced. To design and develop various solid rocket processing procedures which while maintaining the performance gains, lead to significant reductions in manufacturing costs.

TITLE: 1.3 Reduced Smoke Propellant Aging Study

Performance Period: Mar 89 - Oct 92

OBJECTIVE: Evaluate numerous Class 1.3 reduced smoke propellants to obtain early information on potential service life limiting problems and to develop methodology for predicting service life of present and anticipated designs of air-launched missiles containing Class 1.3 reduced smoke propellants.

TITLE: Aging Simulation Motor

Performance Period: Jun 89 - Oct 92

OBJECTIVE: Investigate the motor factors that influence and are influenced by aging in the rocket motor. Identify those motor design features that can be modeled in an aging simulation (hardware). Incorporate these features into a simple design that can be periodically evaluated. A standard for industry design will be made for single or multiple simulators that duplicate motor phenomena.

TITLE: Solid Fuel Ramjet Booster (SFRJ)

Performance Period: Mar 89 - Oct 91

OBJECTIVE: To design and develop a SFRJ booster compatible with future SFRJ missile misison scenerios. This will be done with input from AFWAL/PO and ASD using their latest mission analysis and desired features.

FY 89 BALLISTIC MISSILE PROPULSION PLANNED NEW STARTS

TITLE: Aging and Surveillance Gage Verification

Performance Period: Jul 89-Sep 93

OBJECTIVE: Numerous gages and sensors are available for measuring propellant and case bond chemical and structural changes occurring during application of thermal and structural loads. However, the ability of these gages and sensors to monitor subtle changes occurring in the propellant grain and case bonds during long term aging must be verified. This program will demonstrate and verify the capability of "in situ" stress and strain gages and sensors to measure changes in missile motor structural properties during transport, storage and deployment. It will also verify the reliability of stress and strain gages and sensors during missile motor aging and surveillance.

TITLE: Accept/Reject Technology

Performance Period: Oct 88-Sep 92

OBJECTIVE: Non-destruction valuation (NDE) technology is at a point where the capabilities of the machines exceed the ability to interpret the data they produce. This program will enhance the ability to apply NDE data to diagnosis and ranking of defects in solid rocket motors. This program will develop the criteria relating defect type, size and location of service life reliability and ballistic performance using computed tomography (CT) NDE.

TITLE: Pen-Aid/Reentry-Vehicle Propulsion Study

Performance Period: Apr 89-Sep 90

OBJECTIVE: This is an analytical effort to identify propulsion technologies which have the potential to enhance reentry vehicle penetration capability and define required research goals/scope.

TITLE: Novoltex Failure Criteria

Performance Period: Oct 88-Sep 92

OBJECTIVE: Processing failures of two-directional (2D) carbon-carbon (C-C) exit cones and firing failures of rocket nozzle subsystems demonstrate that the current state-of-the-art in rocket nozzle construction techniques must be improved to reduce the risk of failure rocket nozzle subsystems. This program will develop and verify quantitative, multiaxial, stress-strain failure criteria for three-dimensional Novoltex C-C exit cones/nozzles; the developed criteria will allow the prediction of failure and aid the design and analysis of rocket nozzles. Characterization of the failure mechanisms that are operative under complex states of stress and strain will allow insight to those loads occurring during a motor firing.

FY 89 BALLISTIC MISSILE PROPULSION PLANNED NEW STARTS (CONTINUED)

TITLE: Defect Image Analysis

Performance Period: Jun 89-Sep 92

OBJECTIVE: The eye cannot adequately distinguish and position anomalies present within current non-destructive evaluation (NDE) data on nozzles. Advanced computational image analysis would allow anomaly definition and positioning of defects for engineering evaluation and corrective action. This program will incorporate advanced image processing techniques into representative NDE inspection methods employed on solid rocket nozzle components.

FY 89 MULTIPLE APPLICATIONS PROPULSION PLANNED NEW STARTS

TITLE: Boundary Layers Code Validation

Performance Period: Oct 88 - Oct 92

OBJECTIVE: Large area ratio nozzles used in space engines cannot be accurately analyzed for performance and heat transfer because the boundary layer thickness and viscous flow losses are unknown. Validated new boundary layer models for large area ratio nozzles are needed to provide accurate performance prediction for future OTVs, which results in more reliable propulsion systems at a lower cost (due to fewer tests required to verify engine performance). The objective of this project is to obtain data to validate new boundary layer models for large area ratio nozzles.

TITLE: Liquid Rocket Combustion Stability Mechanisms

Performance Period: Dec 88 - Dec 91

OBJECTIVE: There is a need for experimental data to elucidate the behavior of the unsteady flows in liquid rocket chambers. This data will be used to verify models used in improved combustion stability codes. In this manner we can increase the accuracy of combustion stability prediction, which will reduce the development costs of future rocket systems. The objective of this program is to investigate the combustion response of propellant droplets, sprays, and flow fields to flow and pressure oscillations.

TITLE: Bonded Interface Chemical Formulation

Performance Period: Jun 89 - Jun 92

OBJECTIVE: Chemical modification of liner and insulator ingredients can greatly improve their bonding, barrier and insulating properties. This program will develop improved liners and insulators by chemical modification of ingredient properties. This will give the Air Force the ability to tailor liner and insulator formulations for specific applications by chemically adjusting chemical and structural properties.

TITLE: Solid Rocket Motor Analysis Code Consolidation for Space Applications

Performance Period: Jan 89 - Jan 91

OBJECTIVE: No single computer code exists that contains all the features required for a complete structural analysis of current solid rocket space boosters. This program will consolidate existing Air Force structural analysis programs into a single Solid Rocket Motor Analysis Code (SRMAC). Maintainability of the code will be improved by modularizing the software. Such a consolidation will result in improved service life and performance estimates for Air Force Space and Missile Propulsion Systems.

TITLE: Microencapsulation

Performance Period: May 89 - Sep 90

OBJECTIVE: The program objectives are to determine the feasibility of encapsulating solid ingredients and to demonstrate the feasibility of using these ingredients in a state-of-the-art solid propellant. A two phase effort is planned to demonstrate microencapsulation of ingredients for solid rocket propellants. Phase I is a feasibility study to screen encapsulated materials to determine which ingredients can be encapsulated and formulated into a solid propellant. This phase consists of two tasks, a literature search of encapsulation methods with the encapsulated material acquisition and small propellant mixes evaluating the encapsulated materials. Phase II is propellant demonstration in a solid rocket motor. Selected ingredients will be scaled up to 5 gallon mixes for test motor demonstration and property determination.

TITLE: Processing Automation

Performance Period: Apr 89 - Dec 91

OBJECTIVE: Develop and demonstrate an automated one-pint solid propellant mixing facility. The contractor shall develop, or modify existing equipment to automate a one-pint solid propellant mixer at AFAL. This mixer will serve as a model for the rest of the industry. Operational steps that will be considered for automation include ingredient weighing and prebatching, ingredient addition, on-line monitoring of relevant mix parameters, propellant casting, and clean-up. Emphasis shall be placed on approaches that minimize human intervention and enhance safety. Modifications to the mixing equipment will be accomplished if deemed necessary.

TITLE: Energy Conversion and Deposition

Performance Period: Mar 89 - Sep 91

OBJECTIVE: *Investigate* the scientific issues relating to the release of stored energy and subsequent deposition into a working fluid. The approach will build upon the fundamental research currently under contract in the High Energy Density Matter (HEDM) sub-cluster. Promising HEDM compounds from current research will serve as the models for the energy conversion process into kinetic energy of a rc 'et exhaust. The research avenue emphasized may be experimental, analytical or a combination approach. This program will hopefully lead to a demonstration concept for very high specific impulse rockets.

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