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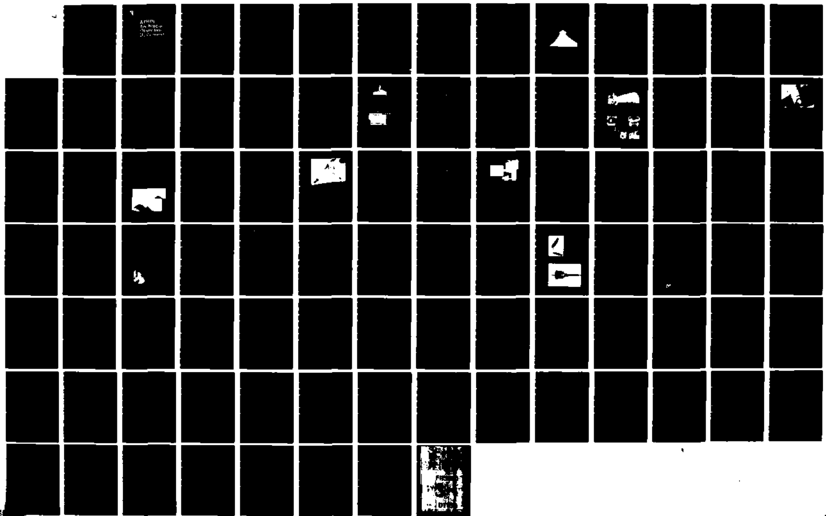

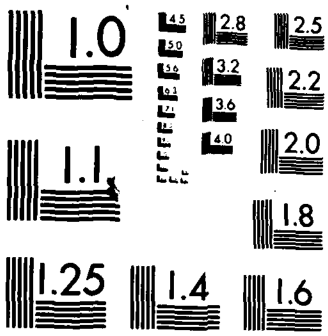

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October 1983

AFRPL Technical Objective Document

FY85

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Air Force Rocket Propulsion Laboratory

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

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Director, Air Force Rocket Propulsion Laboratory

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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 Rocket Propulsion Laboratory between FY 83-89.

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AFRPL TECHNICAL OBJECTIVE DOCUMENT

FY-84

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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 weapon systems. Each Air Force laboratory annually prepares a Research and Technology (R&T) Plan 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 responsiveness 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 is a product 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 R&T Plan.

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 Technical Programs. Classified TODs are available from the Defense Technical Information Center (DTIC) and unclassified/unlimited TODs are available from the National Technical Information Service (NTIS).

The AFRPL TOD contains a general overview of the Laboratory as well as detail program descriptions. The appendix contains a program listing of our FY-85 programs; on-going and expected new programs. The planned new competitive contracted programs are indicated with an asterisk in the listing. Detailed program descriptions for each of these planned new competitive starts, are also contained in the appendix. These program descriptions 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. The detail program descriptions are in the same order as they appear on the program listing.

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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 the 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 writing to Air Force Systems Command/PMPR, Andrews Air Force Base, Washington, DC 20334), 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 Rocket Propulsion 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	1Lt Mark Foster AFRPL/XRX Autovon 350-5344 Commercial (805) 277-5344
Ballistic Missile Propulsion Technology	Mr. Norman J. VanderHyde AFRPL/XRX Autovon 350-5346 Commercial (805) 277-5346
Air-Launched Missile Propulsion Technology	1Lt William Graves AFRPL/XRX Autovon 350-5341 Commercial (805) 277-5341
Multiple Applications Rocket Prop Tech	Mr. Robert A. Biggers AFRPL/XRX Autovon 350-5206 Commercial (805) 277-5206

LABORATORY MISSION

The Air Force Rocket Propulsion Laboratory (AFRPL) is the principal AFSC organization charged with planning, formulating and executing the USAF technology programs for rocket propulsion. In addition, the Laboratory's mission has been expanded to include interdisciplinary space technology. There are two parts to the AFRPL 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 end items. This mission is graphically depicted in Figure 1.

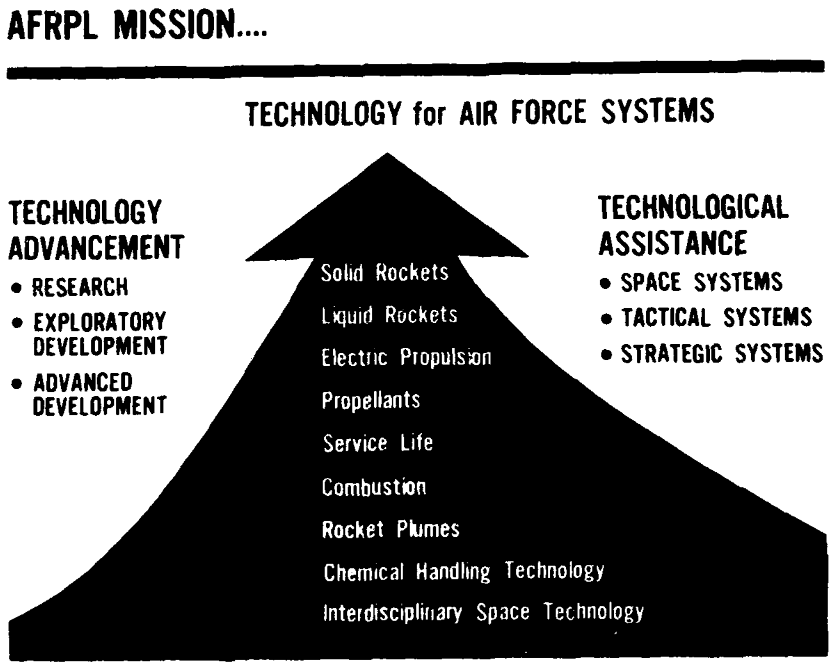

FIGURE 1

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 related disciplines, as listed inside the arrow on Figure 1, which will provide options for the development of future high performance Air Force systems and to prevent technological surprise. The technical support, or technological assistance includes: engineering and scientific consultation, technical direction of programs, managing contractual efforts and executing in-house analytical and experimental programs.

INVESTMENT STRATEGY

1. Background/Rationale

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 planning activities, such as Vanguard, AF 2000, AFSC 1990, and the Military Space Systems Technology Model (MSSTM), and (3) basic technological advances, otherwise known as "Technology Push." We use an in-house program council, made up of the Director 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. We apply the Defense Science Board Catechism, Figure 3, to each of our major thrust areas to insure that the technology focus is correct. 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.

2. Major Thrusts

At the AFRPL, our technical work is carried out in five major thrust (MT) areas: (1) Advanced Propulsion Technology for Ballistic Missiles, MT-A; (2) Improved Rocket Propulsion for Air-Launched Missiles, MT-B; (3) Improved Rocket Propulsion for Space Systems, MT-C; (4) Develop Multiple Application Rocket Propulsion Technology, MT-D; and (5) Develop Interdisciplinary Space Technology, MT-E. These five major thrust areas are shown in Figure 4. The breadth of our rocket propulsion technology program is shown in Figure 5. The inter-relationship of the Laboratory's five major thrusts is shown in Figure 6. Major Thrust D, as its Multiple Application Rocket Propulsion Technology title suggests, encompasses technical disciplines applicable to all of the other four major thrusts. As the overlapping of the circles depict there are technology investigations within each major thrust that are also applicable to the other major thrusts, i.e., advanced nozzle technology in MT-A, Ballistic Missile Propulsion would also apply to MT-C, Space Systems Propulsion. The following paragraphs discuss the areas of investment and their respective payoffs for each of the major technical thrusts.

AFRPL PLANNING PROCESS....

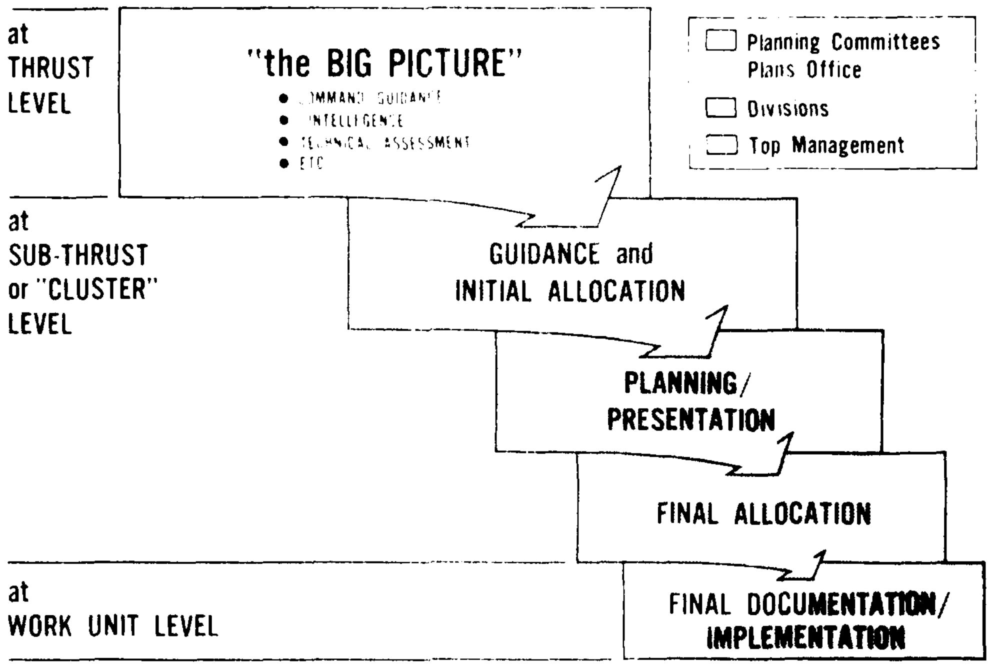

FIGURE 2

"The Catechism" New Testament....

- **What Is It? (Defining the Technology Sufficiently Well to Discriminate it from Other Similar Technologies)**
- **Why is it Important? What Difference Can it Make? (Taking into Account the Nature and Limitation for Current Practice)**
- **What is the Current Status? What is the DoD Program? What Should it be? What is New About the Proposed Effort?**
- **How Long Will it Take? How Much Will it Cost? What Are the Measures of Success?**

FIGURE 3

AFRPL FY85
Major Technical Thrusts....

- **Advanced Propulsion Technology for Ballistic Missiles**
- **Improved Rocket Propulsion for Air-Launched Missiles**
- **Improved Rocket Propulsion for Space Systems**
- **Develop Multiple Application Rocket Propulsion Technology**
- **Develop Interdisciplinary Space Technology**

FIGURE 4

AIR FORCE ROCKET PROPULSION TECHNOLOGY....

PROPULSION for SPACE SYSTEMS

- Launch Vehicles
- Orbit Transfer
- Satellites
- Plume Characteristics

PROPULSION for BALLISTIC MISSILES

- Boost Stages
- Front Ends
- Service Life

PROPULSION for AIR-LAUNCHED MISSILES

- Performance
- Flexibility
- Signature

ACROSS-THE-BOARD PROPULSION TECHNOLOGY

- Combustion
- Mechanical Behavior
- "High Energy" Chemistry

ADVANCED PROPULSION CONCEPTS

INTERDISCIPLINARY SPACE TECHNOLOGY

FIGURE 5

INTER-RELATIONSHIP of LABORATORY MAJOR THRUSTS....

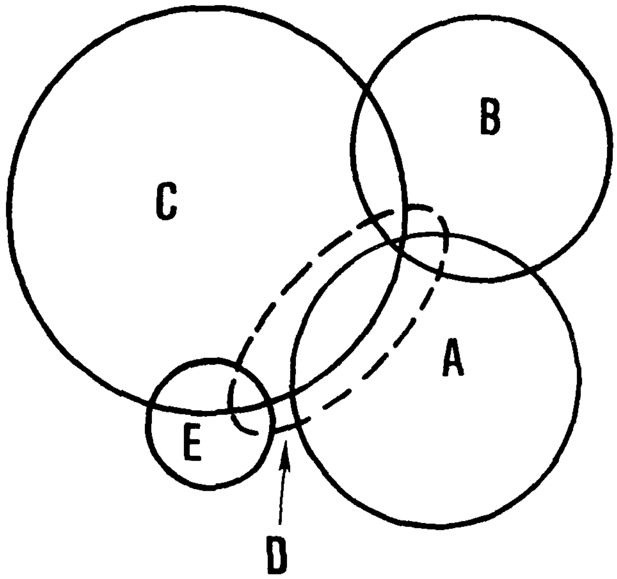

FIGURE 6

a. Advanced Rocket Propulsion Technology for Ballistic Missiles

Future strategic forces must reflect a mix of characteristics that would enhance survivability. Chief among these characteristics is flexibility. This technical thrust is directed toward providing technology to reduce the development risk and cost of providing future survivable enduring strategic forces. Solid rocket motor technologies are being investigated that, when used in a small ballistic missile, could significantly decrease the weight of the propulsion system over systems using present state-of-the-art technologies. Advanced front-end propulsion technologies can also provide additional performance capabilities which can be used for increased strike coverage by providing a high cross-range capability. Lower costs of over 50 percent can be achieved by automating solid motor insulation application techniques and carbon-carbon nozzle fabrication methodology. All propulsion system components, especially propellants must be designed to take the wide temperature and vibration environments that will be imposed by mobile-basing modes. These components are not currently available and must be developed. With the Small ICBM, smaller size, long-life, components need to be emphasized.

b. Improved Rocket Propulsion for Air-Launched Missiles

When considering investment strategy, the area of Air-Launched Missile Propulsion needs to be broken down into three major parts; Air-to-Air, Air-to-Surface and Strategic. By analyzing the Air Force's major concerns in these areas an investment strategy will follow.

Air-to-air is considered to be in the best shape of all these areas. This is mainly due to the newer aircraft and the status of AMRAAM. However, we must increase our force structure through either more assets or more effective force-multipliers. The use of advanced propulsion technology is an integral part of a more effective force-multiplier. Advanced propulsion technology must also consider the impact of weapons integration to the Advanced Technology Fighter (ATF). One of the major concerns of the ATF is low observables. We are currently planning to work this area while also maintaining the propulsion performance and flexibility required for the missions.

The air-to-surface category is receiving renewed interest. The major concern here is the need for standoff. Everyone agrees that standoff is needed. The real question involves how much and what kind. This will definitely be paced by what propulsion technology is available. Our understanding of this concern is reflected by our emphasis for increased performance rocket propulsion systems. Not only do we need standoff for a more survivable system but our assets need to have an increased sortie effectiveness. This means more kills per pass and higher probability of kill per weapon. Our investment in the area of propulsion flexibility addresses this concern. Finally, in the name of more survivability and sortie effectiveness, adequate defense suppression is a must. Our work in the area of low observables addresses the non-lethal aspect from a defensive side of the issue and a combination of all our technologies provides a lethal weapon by not giving the enemy a notice of launch, high performance for fast reaction and standoff, and use of flexiblity to increase the probability of kill.

The strategic part of the picture has three main concerns. First, force modernization by getting newer weapons such as the B-1 and an Advanced Air-to-Surface Missle (AASM). Second, improved force structure through force-multipliers and lower attrition rates. Finally, increasing the survivability of the aircraft and the weapon throughout the mission and to the target. All of these concerns are taken into account through our 6.3A program for an Advanced Air-Launched Motor. This motor is applicable to the AASM. Because of its advanced technology, it acts as a force-multiplier due to lighter weight and increased range capability. The incorporation of propulsion flexibility, by the use of energy management, provides increased survivability since it gives it the ability to defeat the anticipated terminal defenses.

c. Improved Rocket Propulsion for Space Systems

The technology efforts in this thrust cover propulsion for all future USAF space systems: satellites, launch vehicles and orbit transfer/upper stage vehicles. This includes work on solid propellant motors, liquid propellant engines and feed systems, and electric rockets, as well as modelling of the exhaust plume produced by all rockets. Space propulsion technology is taking on an increasing important role as the US is moving in the direction of relying on space assets for force-multiplying functions. Rocket propulsion technology advances will allow the US to attain and maintain space superiority.

Future satellites will require more and more propulsive energy over a longer in-space life period. Rocket system improvements to reduce the propulsion system weight fraction, as a proportion of the total satellite weight, will be a high priority goal. Improved launch vehicle propulsion technologies, for both conventional systems and special mission systems will concentrate on eliminating complex ground operations and maintenance procedures, enabling affordable day-to-day access to space. As our space systems become larger and heavier, increased performance orbit transfer stages will be needed to provide the future increased mission capability and survivability desired. Liquid rocket engine technologies will provide the controllability for moving large, ultra-light, large structure satellites around in space. Electric propulsion systems hold the promise of efficiently providing for a very high altitude capability enhancing satellite survivability in the time of hostilities. Rocket propulsion plume technology will provide the signature data necessary to insure early warning and accurate determination of missile type and destination.

d. Develop Multiple Application Rocket Propulsion Technology

This part of our job is one of very high priority and is increasing in emphasis. This thrust area includes those propulsion technologies that are multi-disciplined and have broad areas or many areas of application. The area can be thought of as developing our core technologies: understanding combustion mechanisms, understanding the chemistry and structural mechanics of solid propellants and the investigation of advanced propulsion concepts.

The revolutionary development of advanced propulsion concepts is a high risk, high payoff area that is very difficult, requiring a lot of mental stretching, but it is critical to the well-being of our country and, in turn, to the Air Force. We are looking over the full spectrum of technological opportunities and attempting to exploit those which look significant and promising. This includes unique approaches and "barrier busters" often associated with high risk. In this category, we have solar thermal and magneto plasma concepts, as well as innovative conventional ways of providing significant weapon system capability improvements. The core technology developments involve phenomenological investigations to insure design tools are produced that allow for rocket systems to be "designed right, the first time" so they can be "made right, the first time." This kind of understanding will eliminate the costly "cut-and-try" method so predominate in any industry that is always advancing the state-of-the-art, such as the aerospace industry.

e. Develop Interdisciplinary Space Technology

The intent of this area is to provide advanced interdisciplinary space technologies for future Air Force systems. This involves working in many multi-discipline technology areas: large space structures, energy, space weapons, automation and contamination. The technology payoff of these multi-discipline areas will enable large aperature sensors, multi-megawatt power, increase satellite survivability with less dependence on ground control, and will provide for increased satellite lifetimes in space. A key feature of this major thrust will be focused on the technology of integration across these multi-discipline technical areas. Integration technology will provide the link between key non-propulsive components of space systems necessary to develop a total system. Likewise, by introducing this technical area into our mission area, it will strengthen our traditional propulsion activities by providing insight to overall system technology problems associated with integrating advanced, new types of propulsion into future satellites and military space vehicles. It is expected that because of the multi-discipline aspect of this major thrust, we will be able to capitalize on technology opportunities for exploiting space.

3. Changes in Thrust Emphasis

The investment strategy this year was significantly shaped as a result of two major influences; the incorporation of the Laboratory into the new Air Force Space Technology Center (AFSTC), Kirtland AFB, NM, and the challenge issued to the Laboratory by Lt Gen Richard C. Henry, then Commander of SD, Los Angeles Air Force Station, CA, for a space propulsion renaissance.

The USAF is dependent on space assets and we will be in space to stay. This is evidenced by the recent formation of the USAF Space Command and the AFSTC. In keeping with this direction, Gen Henry challenged us to develop a renaissance in rocket propulsion technology. We approached the challenge by determining the level of space systems capability that can be enabled by advancements in rocket propulsion. It was the conclusion of the study team, that while there remains a lot of high payoff rocket propulsion work in all of the in-space operational arenas, the enabling path for future efficient space operations is to direct increased technology emphasis on space-based, reusable orbit-tranfser-vehicles. In the propulsion field, this means developing cryogenic propellant propulsion systems, solar/thermal propulsion systems, and then progressing to electric propulsion systems-possibly even nuclear propulsion if break-throughs can be accomplished for efficient in-space nuclear reactors.

While the major influences on our investments have occurred in the space systems area, we have some changes of emphasis in the other major thrusts of our overall mission responsibility. The total picture of the areas of major change of emphasis, within each of our major technical thrusts, is shown in Figure 7. In general, we have had reductions in all of our major thrusts, from previously planned levels of effort, due to declining budgets. We are posturing our Ballistic Missile Propulsion technology toward future flexibile small mobile missile propulsion systems (small missile and advanced ICBM systems). However, we are having to limit our full-scale motor demonstrations which, in turn, will add development risk to any small missile development. Our Air-Launched Missile Propulsion technolgoy efforts will continue to provide high performance motor options for future tactical and strategic weapons system.., but needed priorities have caused us to phase-out our support of rocket booster propulsion for ramjets. We will continue to support booster work that has a mutual benefit to both advanced rocket motor technology and ramjet boosters. Our investments in the Space Propulsion and Multiple Applications technology areas reflect the space influences discussed earlier. The new Interdisciplinary Space technology major thrust is being hampered by austere budgets; however, we are striving to have firm, planned investment areas in this new non-propulsive major thrust.

Changes in Thrust Emphasis....

General

- Reductions in All Major Thrusts — Declining Budgets

Ballistic Missile Propulsion

- Decreased Full-Scale Motor Hardware Demonstrations — Adds Risk to "Small" ICBM

Air-Launched Missile Propulsion

- Termination of Funding for Ramjet Boosters — Technical Expertise Support Will Continue

Space Propulsion

- Decreased Satellite Propulsion Activity
- Increased Activity on Cryogenic. Space Based. Reusable Orbit Transfer Propulsion

Multiple Applications Technology

- Increased Emphasis on Solar/Thermal & MPD Propulsion Tech.

Interdisciplinary Space Technology

- Needs Planned Investment — Limited by Parsimonious 6.2 Budget

FIGURE 7

RESEARCH PROGRAMS

The AFRPL research programs are fully integrated into our five major technical thrust areas. While basic research is usually considered to consist of scientific exploration without any specific military application in mind, we find that a fully integrated program, aimed at specific rocket propulsion discipline technical goals, identifies the gaps in our technical efforts that require detailed scientific investigation in order to achieve those goals. As a result of this approach, our research programs are strongly coupled to our 6.2 (exploratory development) programs and in many cases have arisen from them.

We are pursuing six basic research program tasks in FY 85. The first, rocket propellant ingredient and exhaust chemistry, is primarily addressed to preparing new ingredients to support the Laboratory's solid rocket propellant development efforts. As requirements for new oxidizers, burn rate catalysts, etc. are identified, they are synthesized under this program.

An effort in nozzle technology is the second task. Because nozzle development is currently more an art than a science, this basic research program is providing understanding for our nozzle exploratory development programs. Over a period of years, this program should contribute much to changing the current art to a science.

The third task is combustion technology. We are attempting to provide the basic data that is used to solve exploratory development problems dealing with oxidizer decomposition, combustion instability, etc.

In the plume technology effort, the fourth task, we develop plume models and produce basic data on molecules and condensation mechanisms that can be applied to reducing the amount of smoke in future propellants or to describing the plume signatures.

The fifth task involves investigating advanced propulsion sources. This includes experimentation on developing an understanding of the controlling processes and mechanisms of magnetoplasmodynamic (MPD) propulsion. This area also includes feasibility investigations of advanced propulsion sources capable of producing pounds of thrust at specific impulse levels in the order of 100,000 seconds.

Finally, the sixth and last task is that of propellant mechanical behavior service life. Here we develop models and verify them with experimental data to predict the changes that occur as propellants age. Included is failure criteria development for new missile systems.

The focal point for our research program is:

Mr Robert A. Biggers
AFRPL/XRX
AUTOVON 350-5206
Commercial (805) 277-5206

TECHNOLOGY PROGRAMS

1. Introduction

The Air Force Rocket Propulsion Laboratory's program is organized into five Major 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 technology. The five Major Technical Thrusts are congruent with the five projects under the Laboratory's Exploratory Development program element (62302F). A summary description of the 6.2 program is shown in Figure 8. Our Space and Missile Rocket Propulsion Advanced Development (63302F) projects are aligned with our three applications oriented Major Technical Thrusts. A summary of the 6.3 program is shown in Figure 9.

A discussion of each of the Laboratory's Major Technical Thrusts is provided in the following paragraphs. The underlined phrases, in the following text, corresponds to phrases found in the referenced figures. The Major Technical Thrusts will be discussed in the order shown in the upper right quadrant of Figure 8.

2. Space Systems Propulsion Technology

The Space Systems Propulsion thrust works technology for all future USAF space systems: satellites, launch vehicles and orbit transfer/upper stage vehicles. In addition, as in the past, technology from this thrust will also be applied by the Navy, NASA and commercial industry to their own space systems. This major thrust is illustrated and summarized in Figures 10 through 15.

a. Summary/Objectives

This major thrust is broken into five specific sub thrusts shown in Figure 11 under the "what is it?" heading. Each of these sub thrusts represents an area in which USAF demands for advanced propulsion technology are being addressed.

Performance and durability are two critical parameters for advanced Satellite Propulsion. Future satellites will require more and more propulsive energy over a longer in-space life period. If we do not improve propulsion performance, more than 50 percent of a future satellite's weight will be rocket propellants; in today's satellites, only 10 - 20 percent of the weight is propellant. This increase in weight will significantly increase launch costs and/or will severely limit satellite maneuverability and usefulness. If we do not increase propulsion life (ten years of reliable operation in space) and thruster durability (500,000 -1,000,000 cycles), satellite life will be limited because of propulsion failures.

Rocket Propulsion 62302F ....

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

FUNDING ($×Millions)*:

FY83	FY84	FY85
37.1	35.2	41.2

* FY84 President's Budget

MILESTONES:	QTR/FY
• Demo Hi Temp Resins	3/84
• Demo Reliable C/C Nozzle Attachment Method	4/84
• Droplet Radiator Proof of Concept	1/85
• Space Motor Coning Model	3/85

FIGURE 8

Space & Missile Rocket Propulsion 63302F ....

SUB THRUSTS:
- Space Systems Propulsion
- Air-Launched Missile Propulsion
- Ballistic Missile Propulsion

FUNDING ($×Millions)*:

FY83	FY84	FY85
0	3.3	7.5

* Based on FY85 POM

MILESTONES:	QTR/FY
• Space Systems	
• Modular/Storable Space Propulsion Demo	4/85
• Compact Cryogenic Propellant Feed System Demo	3/84
• Adv. Air-Launched Mtr. Demo	4/85
• Full-Scale Motor Demo for Small ICBM	3/91

FIGURE 9

Space Systems Propulsion....

OBJECTIVE:

- Provide Rocket Propul. Technology for Future USAF Space Systems to:
  - Improve Survivability
  - Enhance Space Superiority and Control
  - Assure Space Access
  - Enable Effective Defense Against Ballistic Missiles

PAYOFFS:

- 50% Increase in Satellite Evasive Maneuver Capability
- Increased Payload to All Orbits

ACCOMPLISHMENTS:

- Demonstrated Satellite Leak Detection/Isolation Feasibility
- Improved Space Motor Perf.

FUNDING ($×Millions):

PE	FY83	FY84	FY85
61101F	0.2	—	—
62302F	11.3	10.9	13.2
63302F	—	1.5	3.6
63406F	—	0.6	1.5
63424F	—	0.5	—
Other	1.5	0.1	0.3

MILESTONES:	QTR/FY
• High Temperature Turbine Cascade Demo	3/85
• Leak Detection/Isolation In-Situ Demo	4/85
• Compact Cryogenic Propellant Feed System Demo	2/87

FIGURE 10

Space Propulsion Technology....

What Is It?

- The Tech Base for Propulsion of All Future USAF Space Systems
  - Satellite Propulsion
  - Special Mission Propulsion
  - Orbit Transfer and Maneuvering Propulsion
  - Space Motors
  - Plumes

Why is it Important?

- Air Force Dependent on Space Assets
- Space Operations Demand Space Superiority
- Enables

What Is the Status?

- Peacetime Architecture
- Survivable Architecture Coming
- Today's Propulsion Insufficient

Measures of Success?

- Ground and Sea Level Firings to Demonstrate Performance

FIGURE 11

To provide the technology needed to assure access to space in times of crisis, we are pushing strongly in the area of Special Mission Propulsion. The Shuttle will be our primary path into space in the 1990's (as is current national policy) but the Shuttle does not provide assured access to space in time of crisis; both the Shuttle and its launch facilities are highly vulnerable to enemy attack; the number of places from which it can be launched is highly limited, and the Shuttle is generally incapable of quick turn-around and rapid-response launch. To solve these deficiencies and still provide militarily meaningful payloads, we are working enabling technologies to improve vehicle engine performance, durability and weight and to provide capability for rapid response launching of a Shuttle complementary military vehicle.

We are also focusing on liquid rocket technology for Orbit Transfer and Maneuvering Propulsion because, even given 100 percent success in the satellite propulsion sub thrust described above, future satellites will be larger and heavier than those in use today to provide increased mission capability and increased survivability. As a result, the Air Force will need to continually increase the performance of the orbit transfer vehicles it uses to move satellites from Shuttle orbit (250 NM) to operational orbits. We will also be driven to increase the number of evasive moves our satellites can make to survive an expanding enemy anti-satellite (ASAT) threat. In both cases, improved propulsion will be critical. Improved propulsion will also be needed to provide the low-thrust, low acceleration (0.2 g and less) propulsion system that future, ultra-light, flimsy, large structure, USAF satellites will require.

Improved performance will also be needed for Advanced Space Motors, though in this case the technology advancement will be provided in solid propellant rockets. With space motors used in launch vehicles (Shuttle and Titan solid boosters), orbit transfer/upper stage vehicles (IUS and PAM-D) and the Miniature Vehicle Anti-Satellite Vehicle, improved motor performance is required across the board.

Rocket Plume Technology involves the exhaust plumes that all rockets produce. Plume signature models describe the brightness and the wave length of all types of rocket plumes, enabling us to develop and operate appropriate sensor equipment to detect and track all missiles launched in the world. Since plume signature is like a fingerprint, we can use plume measurements to determine both missile type and destination, if our models are accurate enough.

As shown in Figure 11, this technology is important because the US is dependent on space assets for critical, force-multiplying functions including early warning, navigation, meteorology and communication. USAF operations demand capability to attain and maintain space superiority. Lastly, space technology is a vital part of defense against ballistic missiles (also discussed in Objectives).

Today's space systems propulsion has the same status as today's space systems: designed and developed to function in a peacetime environment. This peacetime architecture is, however, evolving towards one capable of withstanding some measure of conflict. However, today's propulsion technology base is insufficient to enable the truly survivable architecture of the future. To prove out the capability of our technology to meet the requirements of the future, we will use ground and simulated altitude firings to demonstrate performance.

As shown in Figure 10, the objective of the Space Systems Propulsion major technical thrust is to provide appropriate rocket propulsion technology for future USAF space systems to improve their survivability, enhance USAF ability to attain and maintain space superiority, assure USAF access to space across the full spectrum of conflict and enable effective, affordable defense of the US and our allies against ballistic missiles. Why?

We seek to improve survivability because, as the Secretary of the Air Force has said, "United States' operations in space are an integral part of our military capabilities... a critical element..." Propulsion plays its part in this by enabling satellites to maneuver more to escape enemy anti-satellite systems, by making it possible to orbit heavier satellites (weight being added by more survivabiity gear) and by enabling higher orbits to overfly enemy threat systems.

Enhanced space superiority and control is important to the US for a number of reasons. First, the existence of a credible US threat to enemy satellite systems helps to deter an enemy attack on our satellite assets, thus improving their survivability. The capability to respond to an enemy satellite attack in kind also gives the National Command Authority the choice of a measured response, thus eliminating the need to expand the scope of any conflict for lack of an appropriate quid-pro-quo. Lastly, and most obviously, the ability to control space means that, in the event of a conflict, we can deny the enemy use of his valuable, force-multiplying space assets. Advanced propulsion plays its role by enabling USAF to put up assets capable, if called upon, of seeking out and destroying enemy space assets wherever they may be, thus denying them sanctuaries that are beyond the reach of system's based on today's propulsion.

Third, we want to assure space access to insure that we can replace valuable space assets lost (be it to enemy action or otherwise) whenever and wherever they are needed to provide critical mission support. Here, improved propulsion will eliminate the complex operations and maintenance procedures required today, enabling affordable, day-to-day access to space.

Lastly, advanced propulsion technology is a critical element in the US effort to move towards an effective defense against ballistic missiles. More accurate rocket plume signature models will help track and target enemy ballistic missiles, while advanced propulsion will enable USAF weapons to engage and destroy them.

b. Payoffs

There are many system payoffs for improved propulsion technology. To name just a few:

An advanced storable bipropellant (Nitrogen Tetroxide/Monomethylhydrazine) liquid rocket propulsion system now under investigation promises a 50 percent increase in satellite evasive maneuver capability compared to an equal weight and volume system based on today's best technology (Shuttle). The engine for the propulsion system is depicted in Figure 12.

Modular/Storable Space Propulsion Engine....

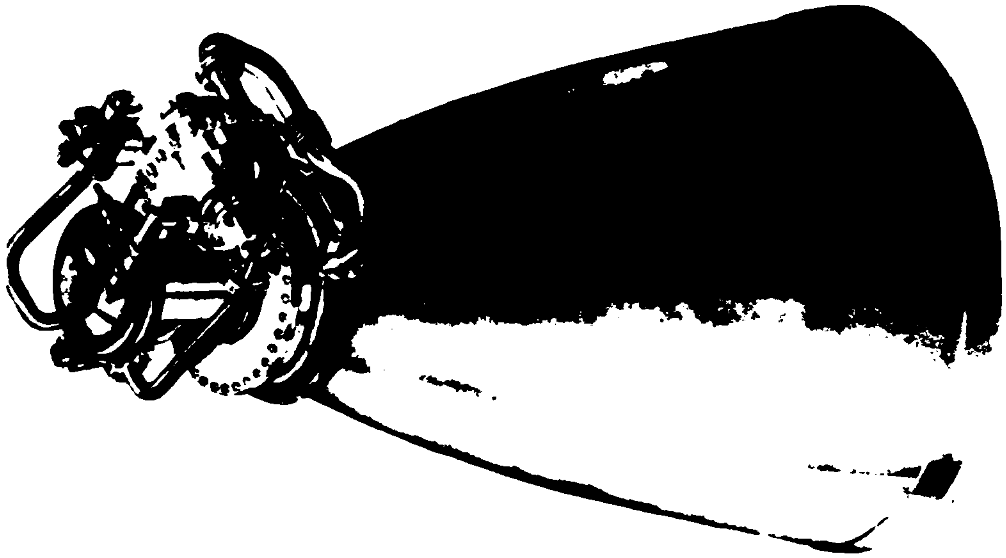

FIGURE 12

IMPROVED PERFORMANCE SPACE MOTOR....

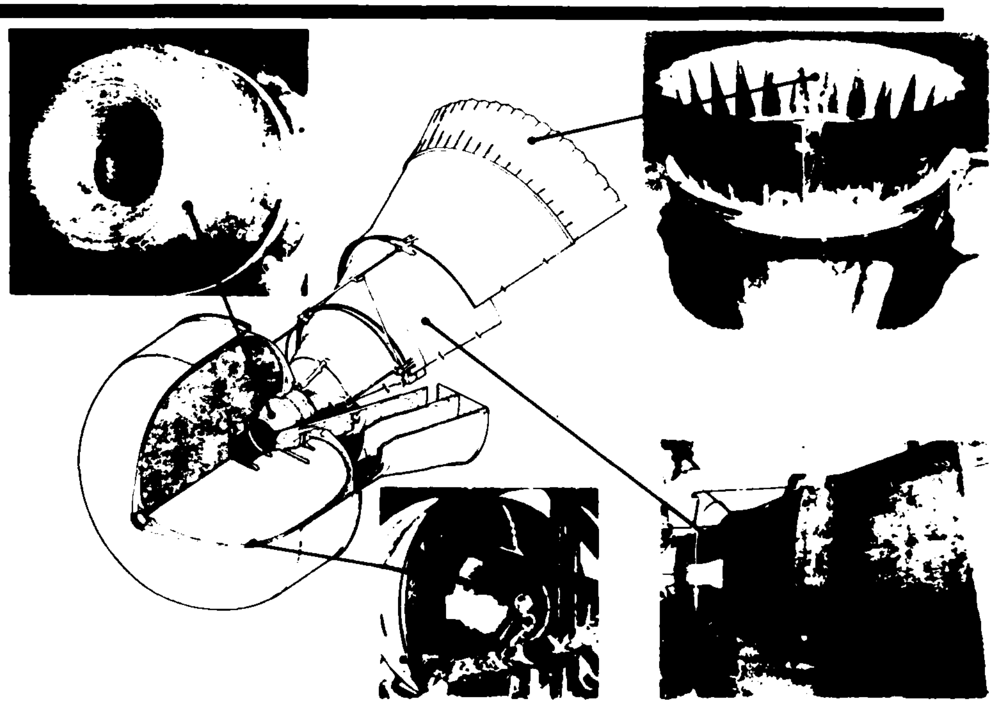

FIGURE 13

Advanced liquid and solid rocket systems for orbit transfer/upper stages will result in increased payload to all orbits. Specifically, improved space motor technology can increase payload weights over that of the Inertial Upper Stage (IUS) flying today; a system based on the advanced storable propulsion system mentioned above would increase the payload carrying capability significantly over the Inertial Upper Stage (IUS).

c. Accomplishments

During the last year, several major milestones were reached in this technical thrust. In order to enable unambiguous detection and isolation of leaks in satellite propellant tanks and lines while they are in use, AFRPL developed and demonstrated (on the ground), a leak detection and isolation concept capable of detecting leaks as low as 0.01 lbm/hr. The concept, based on an acoustic sensor "listening" to lines, also has the advantage of not interfering with the propellant flow or adding another possible failure mode to the system. Follow on work, leading to an in-situ space experiment, has already begun.

The second accomplishment, improved space motor performance, refers to an on-going advanced development program of a solid rocket motor for future IUS growth/product improvement. This motor is designed for maximum compatibility with the existing IUS vehicle and, if the technology being demonstrated were applied to both IUS stages, payload could be increased significantly. Three successful motor firings occurred this year (a fourth, has yet to occur).

d. Milestones

Four significant milestones are shown in Figure 10 as examples of the type of technology AFRPL is developing and when the technology will be ready for users to incorporate into space systems.

AFRPL is currently working technology to improve the life of the high temperature turbine blades in liquid rocket engines. Drawing extensively on turbojet technology, current effort is focusing on application of advanced materials and use of blade cooling (with hydrogen). The milestone shown, a non-rotating blade cascade experiment, will be a demonstration of the effectiveness of the approach currently being defined. Payoff anticipated from this effort is a factor of five to ten increase in turbine blade life, which will significantly contribute to a 75 percent reduction in engine maintenance cost per flight.

In-situ demonstration of leak detection/isolation is the follow-on to the previously discussed accomplishment. The experiment will provide proof of concept in an actual satellite environment showing that the sound of a leak (provided from part of the experiment package) can be discriminated from satellite background noise (upon which there is little data). This technology will be a critical part of the autonomy "package" for future USAF satellites.

Finally, activity on the Compact Cryogenic Propellant Feed System Demonstration, is just beginning. The program will demonstrate an advanced toroidal liquid oxygen tank (shown in Figure 14) and propellant management hardware compatible with the Space Shuttle payload bay (volume and weight restrictions) and space operation (zero gravity, "temperature," vacuum, etc.). This technology, will make possible an increase in cargo-bay length available for payload (compared to an equivalent weight Centaur stage) and an increase in cargo weight capacity (compared to an equivalent length Centaur stage), is critical for the long USAF payloads existing today and in planning. This tankage and feed system program will provide the first and only complete U.S. technology demonstration of a compact cryogenic propellant feed system.

e. Funding

The table in Figure 10 shows the total funding that we plan to devote to the Space Systems Propulsion Technology thrust through FY 86. Program Element 61101F is Laboratory Director's Funds. Program Element 62302F, Project 3058, is for exploratory development and 63302F is a technology base (6.3A) Advanced Development Program Element. The 6.3 funding is for Project 6340 and covers four programs in the years shown.

Two of the four 6.3 programs are scheduled to start in FY 84. The Compact Cryogenic Propellant Feed System program will demonstrate an advanced liquid oxygen tank configuration (toroidal) and associated propellant management hardware for use in Centaur product improvement or an advanced upper stage; payoff for this technology is a more compact, heavy lift upper stage which will enable Shuttle deployment of the long, heavy payloads planned by USAF for the 1990's. The other program, the Modular/Storable Space Propulsion system will provide technology for a minimum weight, high performance, space storable propulsion system which will increase satellite evasive capability and orbit transfer/upper stage payload capacity.

The other two 6.3 programs are scheduled to start in FY 86. One program, the Air-Launched Space Defense Booster, will provide solid rocket motor technology to upgrade the lower stage of the air-launched ASAT to achieve an increase in altitude/range capability. The other, Pulsed Plasma Flight Test, will provide verification of performance and life of an advanced electric propulsion system which will lower the weight of the secondary propulsion systems on future USAF satellites by as much as 50 percent.

Program Element 63406F is Advanced Military Spaceflight Capabilty. AFRPL will be managing the propulsion efforts under this PE. Program Element 63424F is Missile Surveillance Technology. AFRPL will be managing an effort under this PE to model the radiation characteristics of rockets at high altitudes.

Cryogenic Orbit Transfer Propulsion....

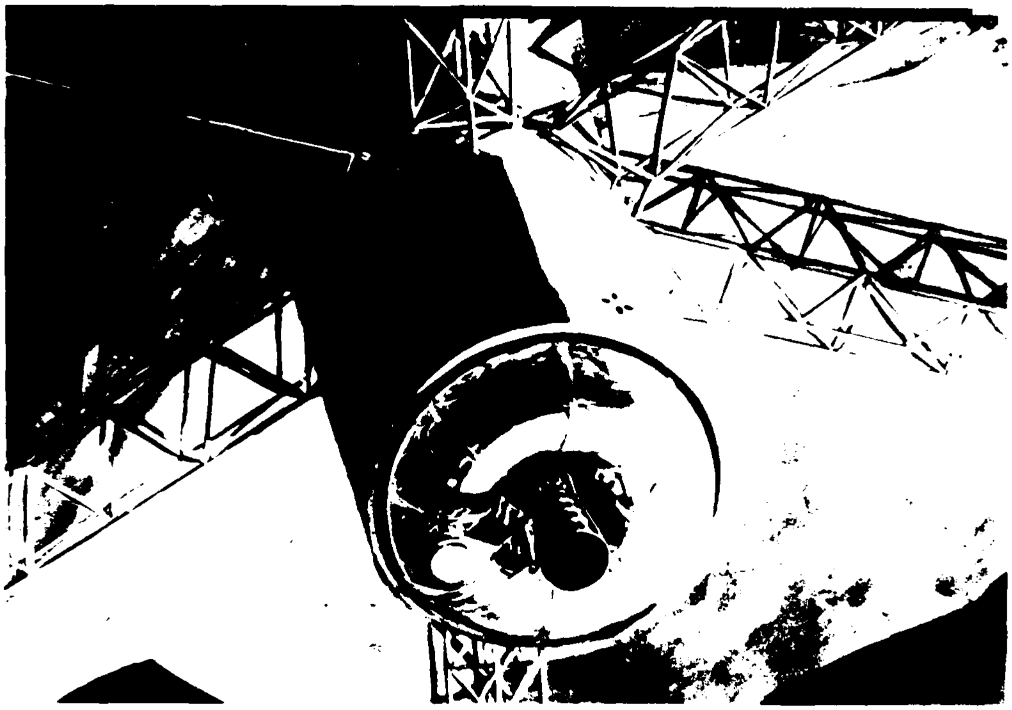

FIGURE 14

Space Systems Propulsion....

Payoff	Systems Significance
• 25% Lighter Special Mission Propulsion	• Assures Space Access of Significant Payloads
• Isp Increase for Modular/ Storable Space Propulsion	• Payload/ Maneuverability Increase
• 67% Decrease in Heat Leak	• 7 Year Life
• Advanced Grain Designs and More Energetic Propellant	• Payload Gain for IUS/PAM-D 2
• 50% Decrease in Satellite Propulsion Weight	• More Mission Payload Per Satellite

FIGURE 15

f. Systems Significance

Figure 15 shows the connection between the technology payoffs of our programs and what they will mean to USAF systems. We see lighter weight high performance propulsion as a key to assuring space access of significant payloads. We see an increase in specific impulse (i.e., push per pound of propellant per second) for the storable engine discussed above as providing a payload increase for a future orbit transfer stage or an increase in satellite maneuverability. We see a 67 percent decrease in heat allowed to leak into reactant tanks as the most critical step toward an affordable space based laser. Advanced solid rocket motors, as already discusssed, can increase IUS/PAM-D 2 payload. The decrease in satellite propulsion weight we will provide will make it possible for each satellite to carry more mission payload. And lastly, we see our improved plume signature capability as improving our early warning and ballistic missile defense capability.

3. Interdisciplinary Space Technology

Interdisciplinary Space Technology (IST) is currently the smallest of AFRPL's major thrusts. IST focuses work on the multi-disciplinary non-propulsive technology areas in which advances will be required to make possible the USAF space systems of the 1990's. This major thrust is illustrated and summarized in Figures 16 through 20. IST is a broadly based multi-disciplinary technology area which we see as a catalyst and focus for USAF Laboratory activity concerned with space systems. Thus far, we have opened five areas of effort or sub thrusts, as shown in Figure 17 under the "what is it?" heading.

a. Summary/Objectives

In the Large Space Structure Dynamics and Control area, we will be working enabling technologies for the large USAF space systems now being conceptualized. To provide the required mission capability, these systems will be larger than anything yet put into space (as much as hundreds of meters in diameter and length - more than ten times as big as the Space Shuttle); to get into orbit though, these structures must also be as light as possible. As a result, these structures will be unprecedented in size and flexibility, requiring technology advances in deployment dynamics and the interaction of control, structure dynamics and thermal management. Size comparisons and the challenges are shown in Figure 18. This sub thrust will focus on and catalyze these technology advances. This sub thrust will also provide the technology enabling fine pointing of space systems that must also have high slew rates to engage multiple enemy targets.

In the Space Defense Concepts sub thrust, we are developing technology for advanced space weapons. While specifics are classified and will not be discussed here, for clarity sake we must point out this sub thrust is not working on lasers or other directed energy weapons.

Interdisciplinary Space Technology....

OBJECTIVE:

- Provide Interdisciplinary Space Technology for Future USAF Space Systems to:
  - Improve Survivability
  - Enhance Space Superiority and Control
  - Enable Defense Against Ballistic Missiles

PAYOFFS:

- 40% Increase in Satellite Life
- 400% Reduction in Radiator Weight for High Power Space Systems

ACCOMPLISHMENTS:

- Formulated Two Have Busk Concepts
- Liquid Droplet Radiator Concept and Key Technologies Defined

FUNDING ($×Millions):

PE	FY83	FY84	FY85
61101F	.2	—	—
62302F	2.4	3.5	4.9

MILESTONES:	QTR/FY
• Spacecraft Contamination Problem Solving Guide Complete	2/83
• Flexing Structure Control Lab Experiments Complete	2/84
• Autonomous Failure Prediction Method Available	3/84
• Liq Drop Radiator Sys Demo	4/87

FIGURE 16

Interdisciplinary Space Technology....

What Is It?

- Catalyst and Focus for USAF Labs in Space Technology
  - Large Space Structure Dynamics and Control
  - Space Defense Concepts
  - Thermal Control
  - Contamination
  - Satellite Autonomy

Why is it Important?

- Air Force Dependent on Space Assets
- Space Operations Demand Space Superiority

What Is the Status?

- Interdisciplinary Enabling Technology Base Missing
- AFRPL Effort Underway 1½ Yrs

Measures of Success?

- Ground and Space Experiments Demonstrating
- Concept Feasibility and Performance

FIGURE 17

Large Space Systems Pose Unprecedented Challenges....

- Size
- Flexibility
- Interactions

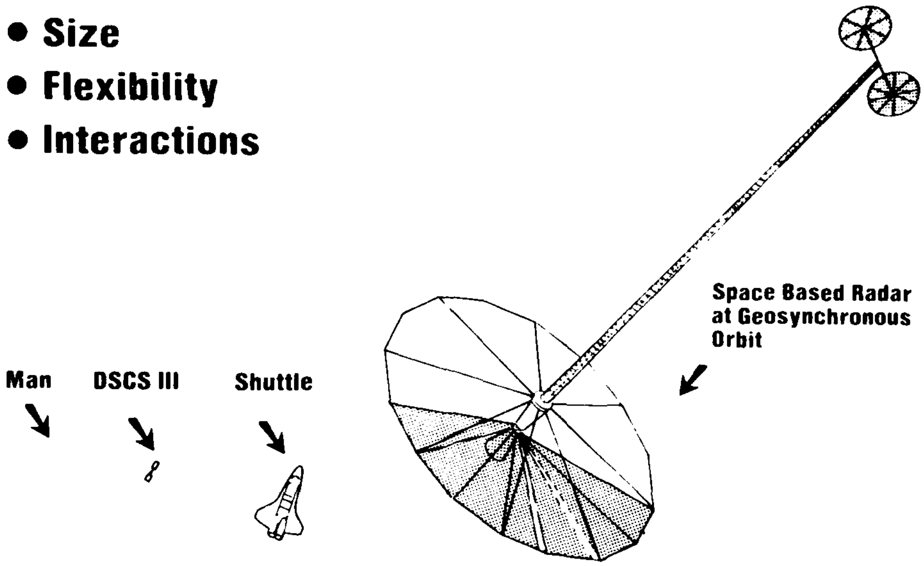

FIGURE 18

Spacecraft Contamination....

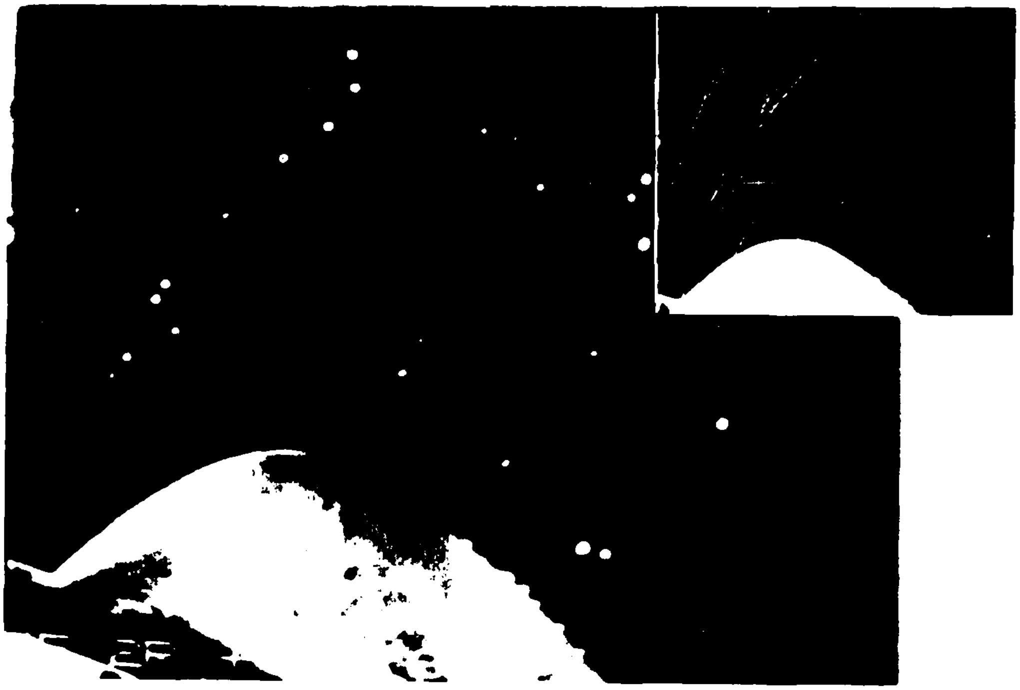

FIGURE 19

Thermal control is also a key area for future space systems and thus is another of IST's sub thrusts. A variety of studies are showing that the power requirements of future satellites will far exceed those of current systems. Since no system is 100 percent efficient, this also means that the waste heat that these future satellites will have to dump into space will also far exceed current levels. This sub thrust is focusing on this aspect of energy management to provide the technology needed to meet these thermal control requirements with the minimum system weight penalty.

Satellites in space are, in reality, flying in small clouds of, for lack of a better work, "dirt." Some of this "dirt" is exhaust products from the satellite's own rocket thrusters; Figure 19 shows some of the contamination (and its trajectory in the inset) from the Shuttle's Reaction Control System. Some more of this dirt is baked out of the satellite's electronics when they are turned on, while some is coolant or propellant leaking into space. But regardless of the source, this dirt can severely impair satellite function by contaminating sensors, thermal control surfaces or solar panels. Thus, in the Contamination sub thrust, we will develop technology to minimize the contaminants produced by future satellites, develop surfaces that are less sensitive to contamination, develop design techniques to minimize the amount of contamination that will get onto sensitive surfaces and develop on-orbit cleaning techniques for those sensitive surfaces which cannot be protected from contamination. Plume contamination models which describe where rocket exhaust products go after leaving the rocket nozzle, are important tools for our spacecraft designers in preventing premature satellite failures caused when critical spacecraft surfaces become dirty and opaque.

Satellite Autonomy is the fifth and final of this major thrust's sub thrusts. This sub thrust will provide technology and techniques that will enable future satellites to make more of their day-to-day decisions and perform more of their routine housekeeping chores without need of outside direction thus increasing their independence of ground facilities an increasing their survivability.

As shown in Figure 17, this technology is important because the Air Force is using its space assets for critical, force-multiplying functions (e.g., communications, meteorology, navigation, early warning). In order to insure the availability of these assets, the US must have the capability to attain and maintain space superiority: to deter enemy attack on our assets, to destroy enemy systems attacking our satellites and, if required, to deprive the enemy of use of his space assets. IST is also important because it is a critical element in enabling effective defense against ballistic missiles.

As Figure 17 shows, we will measure our success in ground and, where required, space experiments demonstrating concept feasibility and performance.

As shown in Figure 16, the objective of the Interdisciplinary Space Technology major technical thrust is to provide interdisciplinary space technology for future USAF space systems to improve their survivability, enhance USAF ability to attain and maintain space superiority and enable defense against ballistic missiles. Rationale for these objectives is similar, in some cases identical to those discussed for the Space Systems Propulsion major thrust.

We seek to improve survivability because operations in space are an integral part of our military capabiities. IST plays its part in this by enabling a greater degree of satellite autonomy than is currently possible and by increasing satellite life.

Enhanced space superiority and control is important to the US for a number of reasons. First, the existence of a credible US threat to enemy satellite systems helps to deter an enemy attack on our satellite assets thus improving their survivability. The capability to respond to an enemy attack upon our satellites in kind also gives the National Command Authority the choice of a measured response, thus eliminating the need to expand the scope of any conflict for lack of an appropriate quid-pro-quo. Lastly, and most obviously, the ability to control space means that, in the event of a conflict, we can deny the enemy use of his valuable, force-multiplying space assets. IST will provide enabling technologies to permit high-power space-based directed energy weapons, to provide enhancement of current ASAT systems, to locate enemy assets in space and to provide alternate methods to negate enemy space assets.

Lastly, IST is also a critical element in the US effort to move towards effective defense against ballistic missiles. IST will provide large space structure control to enable space radars for detection and tracking of ballistic missiles. It will also provide radiator technology needed for future space-based systems.

b. Payoffs

As shown in Figure 16, the technologies in this thrust will result in major system improvements. Our work to control spacecraft contamination will increase satellite life up to 40 percent. Our work on Space Defense Concepts will provide significantly improved and unique ASAT capability. Lastly, our work in thermal control will reduce radiator weight for high power space systems up to 75 percent.

c. Accomplishments

The most significant accomplishments of the last year is shown on Figure 16. We defined concepts and technologies needed for an advanced thermal control system, the liquid droplet radiator (depicted in Figure 20). The droplet radiator is a system in which liquid droplets are "tossed" through space from a droplet generator (think of it as a shower head that produces a very fine spray) to a collector; while the droplets are in space, they radiate heat. Because small droplets are theoretically the most efficient radiating "design" (i.e., they have the least mass/weight per unit of heat dumped), the liquid droplet concept is extremely promising.

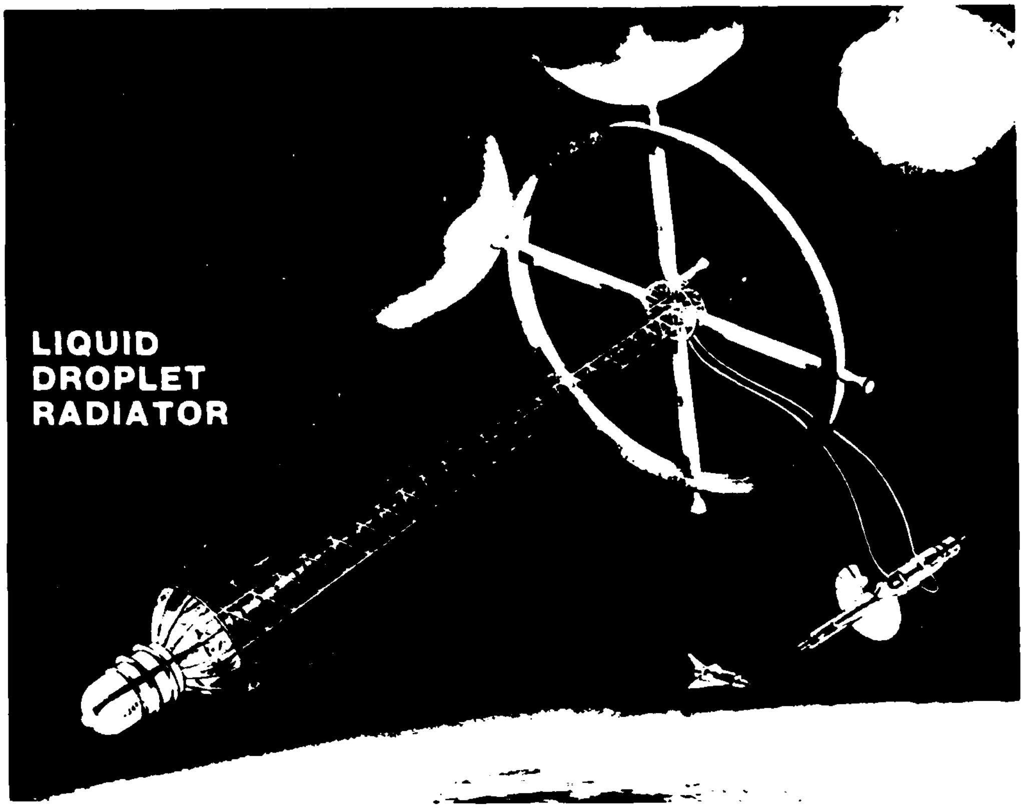

FIGURE 20

d. Milestones

A sampling of the milestones for this major thrust is shown in Figure 16. As this is being written, we are completing work on a spacecraft contamination problem solving guide. This guide, in effect a primer on contamination, summarizes the state-of-the-art of contamination prediction and prevention for spacecraft designers and operators to help them prevent and/or solve their spacecraft problems.

The second milestone, completion of flexing structure control laboratory experiments, will provide verification of the utility of flexing structure control laws currently being developed to permit high slew rates for large space structures. A high slew rate will be required by the small space-based atmospheric surveillance systems or lasers such as might be deployed by the Space Shuttle in the near-term. This principal technology challenge will be attaining high slew rates without deforming surfaces enough to seriously degrade performance (optical precision is required).

We will also complete work on an autonomous satellite failure prediction technique by FY 84. This technique will, in essence, consist of algorithms matching the thought processes today used in satellite control facilities. The result will be satellites more able to handle their own day-to-day housekeeping chores.

Lastly, a system demonstration of the liquid droplet radiator concept will be conducted in FY 87. Key to the investigation will be demonstration of droplet formation and collection without loss of significant portions of the system working fluid. Minimizing the mass/weight of the droplet generator and collector will also be a challenge.

e. Funding

The table in Figure 16 shows the total funds that we plan to devote to the Interdisciplinary Space Technology thrust area through FY 86. Program Element 62302F, Project 2864, is for exploratory development. Program Element 61101F is Laboratory Director's Funds.

f. System Significance

We see the greater pointing accuracy resulting from our large space structure dynamics and control work as enabling a decrease in the number of satellites required for defense againsts ballistic missiles. We see a factor of four reduction in radiator weight from liquid droplet radiator as enabling for high power (greater than 500 KW) space based directed energy weapons for defense against ballistic missile and anti-satellite missions. We see our contamination reduction work as increasing satellite life up to 40 percent. Lastly, we see our work in satellite autonomy as decreasing satellite dependence on vulnerable ground stations.

4. Air-Launched Missile Propulsion Technology

The Improved Rocket Propulsion for Air-Launched Missiles major thrust works technology for tactical and strategic, air-to-air and air-to-surface missiles. Technology from this thrust has also been applied by the Army and Navy to surface-launched, tactical missiles. This major thrust is illustrated and summarized in Figures 21 through 25.

a. Summary/Objectives

The technology in this major thrust falls under three categories or sub thrusts shown in Figure 22 under the "what is it?" heading. The first is technology that will lead to Improved Motor Performance. These include lower weight materials such as composites, higher energy propellants for more thrust, and analytical methods to predict service life that will aid in increased operational life. Figure 23 shows composite case technology integrated into an improved motor design for increased performance. These technologies help meet all of the objectives of this thrust (Figure 21). Improved motors provide a missile of the same size and weight that can go farther, get there faster and/or carry more payload. Improved motors also let you build smaller, lighter missiles that go as far, get there as fast and/or carry as much as the heavier missiles that are built today. If missiles are smaller our planes can carry more of them. This results in more munitions on target, improved probability of kill and a higher sortie rate through increased mission survivability.

Air-Launched Missile Propulsion....

OBJECTIVE:

- Provide Propulsion Technology for Future USAF Missile Systems to:
  - Deliver More Munitions on Target
  - Improve Probability of Kill
  - Increase Mission Survivability

PAYOFFS:

- Increase in Standoff Capability
- Incr. Launch Accept Region
- Incr. in Weapons Loadout

ACCOMPLISHMENTS:

- Flight Qualified Radial Pulse Mtr.
- Developed Asbestos-Free Insulation

FUNDING ($ × Millions):

PE	FY83	FY84	FY85
62302F	7.8	7.0	7.0
63302F	—	1.5	1.9

MILESTONES:	QTR/FY
• Develop Pulse Firing Logic	4/83
• Demo Hi Temp Resins	3/84
• Demo Min Signature GAP Prop.	1/85
• Demo Laser Arm/Fire Device	3/85
• Durable Case Demo	4/85
• High Pressure Propellants	4/86

FIGURE 21

Air-Launched Missile Propulsion....

What Is It?

- Improved Performance Motors
- Propulsion Flexibility
- Plume/Propellant Signatures

Why is it Important?

- Increase Missile Lethality and Cost Effectiveness
- Enhance Survivability of Missile and Aircraft
- Increased Firepower Against Multiple Threats/Superior Numbers

What is the Status?

- SRAM Technology
- AMRAAM Technology

Measures of Success

- Motor Firings
- Flight Verification Data

FIGURE 22

Performance....

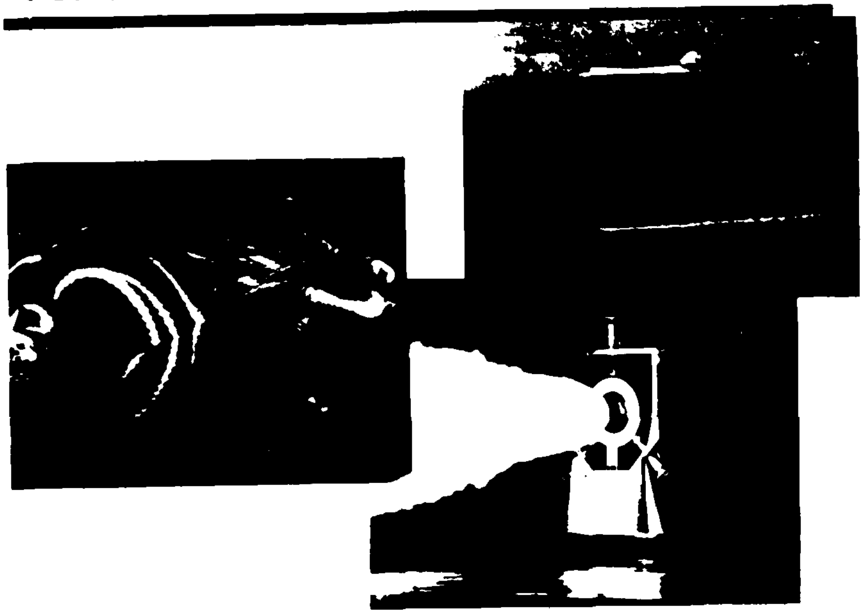

FIGURE 23

The second category provides for Propulsion Flexibility (Figure 22). Typically, the design of the propulsion subsystem for a missile consists of a series of compromises to meet conflicting requirements. By increasing the flexibility of the propulsion so that the energy management can, to some extent, be redesigned at launch or in flight, some of the design compromises that degrade performance in a given particular mission can be eliminated. The technology which allows for this capability is the pulse motor in conjunction with a firing logic. The mission flexibility as a result of coupling this logic is depicted in Figure 24. These technologies also meet the major thrust objectives but provide the greatest potential in increased probability of kill. This supplies a force-multiplier capability that is crucial to the air-to-air battle of the future.

The final category deals with missile Signatures and is made up of two sub thrusts (Figure 22). The technologies involve propellants and plumes. The problem is characterizing many propellant properties to achieve the correct formulation for actual aircraft environments while eliminating the plume. The propellant technology is concerned with providing a propellant that has low observable exhaust species, such as visible, infrared, and radar, while maintaining the ballistic and mechanical properties necessary to preserve performance. The plume technology involves developing computer prediction codes for plume signatures that are crucial to the propellant technology and the sensor design community. This technology results in an increased probability of kill by not allowing the enemy to determine if they have been fired upon and also increases the mission survivability by maintaining the low observability of the launch aircraft.

When comparing these technologies to the major thrust objectives the answer to why is this technology important becomes evident (Figure 22). Through the use of flexibile propulsion one can increase the kill probability of a missile. This means a more lethal missile and even if the technology increases the cost per missile a more mission effective missile can result in a more cost effective missile. By decreasing the signature of the missile it becomes more survivable and doesn't detract from the aircraft survivability but enhances it. This results in a higher sortie generation capability through reduced attrition. Finally, through the use of improved performance motors an aircraft can have a force-multipling weapon which gives it the increased fire power required to meet a numerically superior threat.

The current status of the technology for air-launched missile propulsion is the Short Range Attack Missile (SRAM) and the Advanced Medium Range Air-to-Air Missile (AMRAAM). SRAM is a strategic missile. It is an end burning pulse motor that could benefit from increased performance and reliability. The application of new technology to this area will show extreme payoffs. The AMRAAM is the newest tactical missile but is not operational yet. Introducing new technology into this area will provide a Pre-planned Product Improvement (P^3I) with increased flexibility. The measures of success for this technology will be static motor firings and data from flight tests for concept verification.

b. Payoffs

The bottom line of all this technology is it will improve the ability of US forces and our allies to engage and destroy the enemy wherever he is and to survive to do it repeatedly. Rocket propulsion technology will do this by helping to make missiles more lethal and our aircraft more survivable. How the technology does this is listed in Figures 21 and 25. By increasing the standoff capability of missiles by 50 percent the survivability of assets goes up dramatically since they are not expossed to the defenses. An increase in the launch acceptability region gives tacitcal fighters a force-multiplying effect allowing them to engage more enemy assets at a greater distance with an increased probability of kill. This will also add to a kill before shoot/detect capability. Finally, this technology will allow an increase in weapons load-out due to weight savings. This also gives the fighters and bombers a force-multiplying effect by increasing the fire power of each aircraft.

c. Accomplishments

There were two major accomplishments achieved in air-launched missile propulsion in the past year. The first was that we flight qualified two pulse motor designs. Over 40 motors were fired with coast times between pulses demonstrated in excess of design flight times. This showed that the two pulses were truly independent. The second accomplishment was the development asbestos-free insulations. These insulations, which are required for rocket motors, replaced asbestos fibers with polymeric fibers and resins. The result was a comparable insulation with improved mechanical and processing properties which is also transferable to almost any other application that an asbestos insulation is used in.

Flexibility....

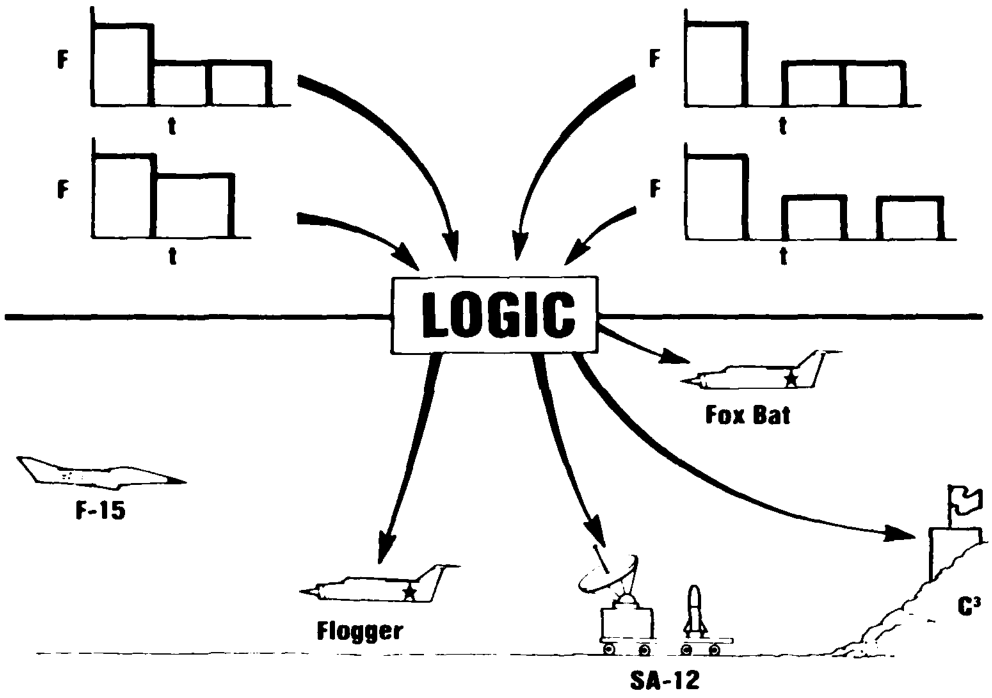

FIGURE 24

Air-Launched Missile Propulsion....

Payoff	System Significance
• 10-15% Weight Reduction	• Range Increase • Increased Payload • Increase in Weapons Loadout
• Increased Missile Velocity	• Reduced Time to Target • Increased Weapon Survivability
• Range Increase	• Kill Before Detect/Shoot • System F-Pole Increase
• Increased No Escape Zone	• Increase Effective Firepower • Increase Cost Effectiveness

FIGURE 25

d. Milestones

AFRPL is currently completing a program that will develop a pulse firing logic for the radial pulse motor. This firing logic uses guidance data to determine the best coast time and firing time of the second pulse that will provide the most desired target intercept. Results from this program are showing an increase in launch range over the current AMRAAM.

Another milestone is the demonstration of high temperature resins. These resins will be used in composite cases for solid rocket motors. The resins will increase the temperature capability of the case. This will allow for more aeroheating capability which will make feasible a higher speed missile.

The demonstration of minimum signature Glycidal Azide Polymer (GAP) Propellant is planned in FY 85. This ingredient, GAP, will return the energy that has been lost by going to a minimum smoke propellant. It is also expected to solve some other concerns of minimum smoke such as the burn rate limitations and the hazard classification.

A laser arm fire device is also planned for demonstration in FY 85. This device would replace the current mechanical device on each missile with a central, aircraft internal, laser that would distribute arm and fire commands through fiber optic lines to the missile. This will be a reusable one time cost item, whereas the mechanical device is a one per missile non-reusable system. This would lead to great cost savings.

With the advent of composite case technology, the demonstration of composite case durability in FY 85 is the last step in proving its ability for long operational life under the air-launched environment. This program will subject composite case motors to dynamic loads, vibration loads, temperature cycles and handling environments. The result of this program will be to prove the integrity of composite cases for air-launched applications.

Finally, a demonstration of high pressure propellants is scheduled for late FY 86. This will demonstrate the ballistic control of propellants at higher pressures than is now possible. This will result in increased performance due to higher thrust capability.

e. Funding

The table in Figure 21 shows the total funds that we plan to devote to the Air-Launched Missile Propulsion Technology major thrust area through FY 86. Program Element 62302F, Project 3148, is for exploratory development and 63302F is a technology base (6.3A) advanced development program element. The 6.3 funding is for Project 6339 and involves two programs through FY 86, the Advanced Air-Launched Motor Technology demonstration and the Low Observables Motor Demonstration.

f. System Significance

Figure 25 shows the connection between the technology payoffs and what they will mean to USAF systems.

5. Ballistic Missile Propulsion Technology

The Ballistic Missile Propulsion major thrust provides the technology for improved performance, reduced development risk, and increased reliability of booster, upper stages, and payload delivery stages. Principal efforts include the evaluation and demonstration of advanced booster rocket motor component options to provide range or payload increases or to decrease missile size; front-end propulsion system technology to increase the accuracy and mission flexibility of weapons delivery systems; carbon-carbon rocket nozzle and exit cone technology for increased reliability/survivability and reduced cost; and development of technology to accurately and inexpensively determine solid motor service life. This major thrust is illustrated and summarized in Figures 26 through 31.

a. Summary/Objectives

The objective is to provide propulsion technology for future Air Force ICBM systems that are survivable enduring forces that provide remote surgical strike of fixed targets. Future ICBMs will need to be mobile and have front-end stage mission flexiblity to enhance their survivability. The new missiles will be small, mobile, self-sufficient, dormant, low cost, and require a low level of maintenance. Technology is required to achieve the small size and performance of the proposed Small ICBM Weapon System. Otherwise, there are large penalties in missile size and weight.

The work in this thrust falls into four sub thrusts or technology groupings as shown in Figure 27 under the "what is it?" heading. The first sub thrust, Advanced Booster Technology, investigates solid rocket motor components required for continued capability growth of ballistic missiles in terms of increased payload and range with the same size missile. These increased capabilities can provide for improved weapon system effectiveness by allowing the incorporation of additional equipment for increased survivability and increased payload. The second sub thrust, Nozzle and Exit Cone Technology, investigates new carbon-carbon nozzle designs and materials, develops simple and reliable processing methods, and evaluates exit cone attachments. These capabilities will permit improved quality control, reduced rejection rate (lower overall costs), and improved and innovative designs. The third sub thrust, Advanced Front-end Propulsion, provides payload propulsion technology for advanced strategic missile front-ends to enhance missile penetration/survivability with improved post boost propulsion and/or increased vehicle weapon delivery footprint. The fourth sub thrust, Ballistic Missile Service Life, provides technologies for Peacekeeper (M-X) missile service life, looks at manufacturing variables, bonded interface survivability, and long term slump properties of propellants. These technologies will reduce O&M costs, insure Ogden ALC gets a workable service life plan for the Peacekeeper missile, and support the "wooden round" concept for the small ballistic missile.

Ballistic Missile Propulsion....

OBJECTIVE:

- Provide Propulsion Technology for Future USAF ICBM Systems to:
  - Assure Survivable. Enduring Strategic Forces
  - Provide Remote Surgical Strike of Fixed Targets
  - Increase Performance

PAYOFFS:

- Weight Decrease — Increased Mobility for SICBM
- Wide Temp Range — Multi-Basing Modes
- Costs Decreased 50%

ACCOMPLISHMENTS:

- Adv. Front Enu Needs Defined
- NEEC/GDS Integration Successful

FUNDING (S×Millions):

PE	FY83	FY84	FY85
61102F	.095	.090	.095
62302F	8.2	6.4	7.0
63302F	—	—	2.2
64312F	.139	0.45	0.294
63311F	.060	—	—

MILESTONES:	QTR/FY
• Evaluate Nozzle Attachments	4/84
• I-H Component Lab Activated	3/85
• Low Burn Rate Propellant Demo	3/85
• C/C Nozzle Surviv. Demo	4/85
• Front End Component Demo	1/86
• Effects of Humidity on Bondline	2/86

FIGURE 26

Ballistic Missile Propulsion....

What Is It?

- Advanced Booster Technology
- Nozzle and Exit Cone Technology
- Advanced Front End Propulsion
- Ballistic Missile Service Life

Why is it Important?

- Increased Performance (Range. Payload. Size)
- Increased Survivability
- Flexible Basing Modes
- Decrease Costs

What Is the Status?

- Peacekeeper Technology

Measures of Success?

- Demonstration of Performance
- Validation of Predictions

FIGURE 27

b. Payoffs

The Ballistic Missile Technology Thrust will provide for significant missile system improvements. Recent analyses have indicated that the incorporation of propellants with high energy plasticizers, composite nozzles, composite exit cones and high efficiency composite motor cases into the booster and upper stages of the present Peacekeeper baseline designs will result in increasing its payload carrying capability and increasing its range. Or it could provide for a decrease in missile weight for the Small ICBM that would enhance its mobility. Multi-basing modes/mobility require a wider operating temperature range than for silo based missiles. The main objective here is the develoment of a propellant that operates efficiently over the entire temperature range. Cost decreases of over 50 percent are expected in the areas of automated motor insulation installation and carbon-carbon nozzle fabrication.

c. Accomplishments

There were two significiant accomplishments as shown in Figure 26.

Advanced Front-end Concepts were defined during this last year. The study compared different propulsion designs for three mission applications which require varying degrees of propulsion system flexibility. Recommendations for what type of propulsion system to use with each size missile application were made.

The Integrated EEC Demonstration demonstrated the Expandable Exit Cone (EEC)-Gas Deployed Skirt (GDS) combination. It was scaled up in size and fired at the AFRPL Space Environment Propulsion Complex under simulated altitude conditions.

d. Milestones

Six significant ballistic missile propulsion technology milestones are shown in Figure 26.

The Evaluate Nozzle Attachments milestone, for the fourth quarter of FY 84, indicates when the different designs for attaching the exit cone to the nozzle will be evaluated. This joint is a critical design point in large expansion nozzles.

The In-House Component Lab activation scheduled for the third quarter in FY 85 will significantly increase the AFRPL capability and future knowledge in composite structures. The effort will include working with Kevlar, graphite, and carbon-carbon materials in an on-site laboratory to provide "hands-on" knowledge of motor component performance.

The Low Burn Rate Propellant Demonstration in the third quarter of FY 85, provides for the verification of the low burn rates needed in the high energy propellant for the small ballistic missile.

The Carbon/Carbon Nozzle Survivability Demonstration provides hot firing data on the latest advanced nozzle designs suitable for the small ballistic missile applications. This will be accomplished in the fourth quarter of FY 85.

The Front-end Component Demonstration in the first quarter of FY 86 is the evaluation of the propulsion components such as new liquid feed systems or solid staged combustion designs for the propulsion/steering for buses or individual RV's.

The Effects of Humidity on Bondline is the study of the degradation of the liner, insulation, propellant, case, etc., that make up the entire bond system, by moisture. With composite motor cases instead of steel, moisture diffuses through the case very rapidly. The study is scheduled for completion by the second quarter of FY 86.

e. Funding

The table in Figure 26 shows the funds that we plan to apply to the Ballistic Missile Propulsion Technology thrust area. The 61102F research funding is applied to programs that are developing a better understanding of carbon/carbon nozzles. The exploratory development efforts are carried out in Project 3059 of Program Element 62302F. The advanced development effort, under Program Element 63302F, is the Advanced Strategic Missile Propulsion Demonstration program. Program Element 63412F is support from the Peacekeeper Project Office and is primarily for Peacekeeper service life programs.

f. System Significance

The payoffs and their system significance for this Major Thrust are shown in Figure 28. Wide temperature range propellants for mobile missiles will be required because those future missile will tend to be small and volume limited. A premimum will be placed on maximizing the energy content (with wide temperature range) of the propellant per each unit of volume. Higher Expansion Nozzles, Integrated Stage (i.e., common bulkhead to reduce missile weight and lengths), Lighter Cases, and Front-ends are all aimed at increasing missile performance. Automated Insulation Application and Nozzle Quality Control are aimed at obtaining drastic cost reductions. Having a lightweight and reliable Nozzle-Exit Cone Attachment would reduce the failure rate of the nozzle assembly. Understanding the Nozzle Billet Processing for carbon-carbon nozzles would reduce part rejection rates from the present 37 percent to less than 10 percent.

g. Technology Comparison

Figure 29 shows the differences between present Peacekeeper Stage III technology and a pictorial of the new technology that will be demonstrated in the next few years within this thrust. The grain design, igniter, case advances, propellant, and nozzle design all combine to give increased performance.

Ballistic Missile Propulsion....

Payoff	System Significance
• Wide Temp Range Propellants	• Mobility/Basing Modes
• Higher Expansion Ratios	• Increased Performance
• Automated Insulation Application	• Decreased Cost
• Integrated Stage Reduced Inert Weight	• Increased Performance
• Lighter Cases	• Increased Performance
• Lighter Front Ends	• Smaller Size/ Increased Performance
• Nozzle Quality Control	• Reduced Cost
• Nozzle-Exit Cone Attachment	• Reduced Failures
• Nozzle Billet Processing	• Rejection Rates From 37% to < 10%

FIGURE 28

Ballistic Missile Propulsion....

Peacekeeper Stage III

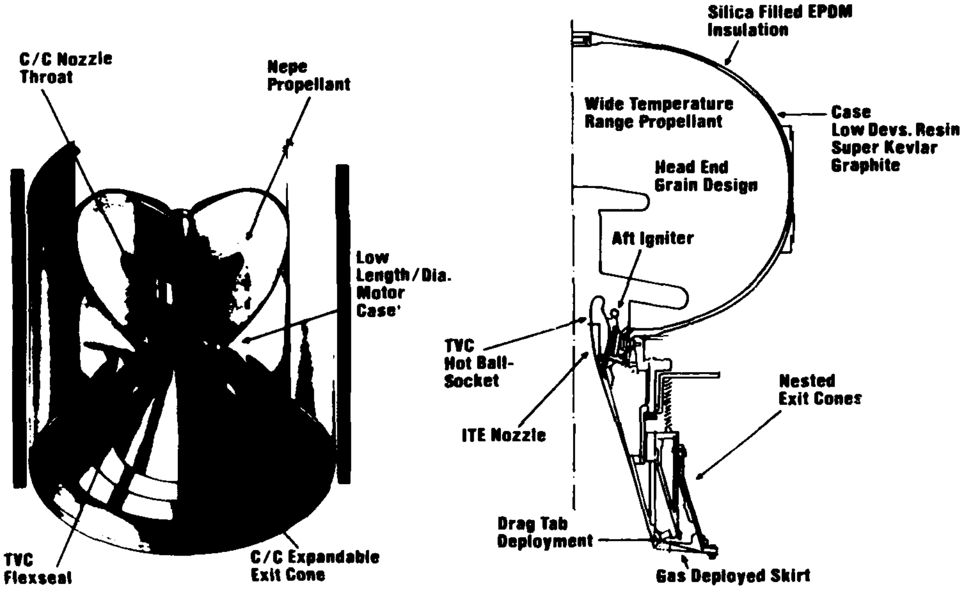

FIGURE 29

The Advanced Front-end Propulsion Chart (Figure 30) shows that the technology can result in a 60 percent weight reduction of a liquid hot gas feed system or a 40 percent weight reduction in a solid gas generator system for front end maneuvering. The use of high performance liquid propulsion systems or controllable solid motors in future front-end systems will result in providing an increased footprint capability for weapons delivery. The increased footprint capability can provide for an overall increase in target selectivity or increased mission planning flexibility. The Propellant Service Life chart (Figure 31) shows the pitfalls and waste that can occur without an understanding of factors that go into service life. Of special importance is knowing when the motors fail and by what mechanism.

6. Multiple Application Rocket Propulsion Technology

This major 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 of rocket propellants and ingredients on the environment, and evaluates the feasibility of advanced concepts for rocket propulsion. This major thrust is illustrated and summarized in Figures 32 through 35.

a. Summary/Objectives

The work in this thrust is thought of as the general technology or "core technologies" that serve as building blocks to the other laboratory major thrusts. Generally, in this thrust the advances tend to be incremental and provide a broad base of research and applied technology to provide information that contributes to the solution of existing problems and looks forward to step function improvements or even to breakthroughs. As shown in Figure 33, under the "what is it heading" this thrust takes the fundamental physical sciences to generate engineering problem solving tools. The work that is performed in this major thrust will generate the information bank that new systems will draw from as we attempt to solve the exploratory and advanced development problems. It is conceivable that one or more of these efforts could lead to either a quantum jump in capability or a break-through that will radically change the direction of development of rocket propulsion systems.

Also, in this thrust, we are looking for ways to obtain design data cheaper. We use computers to provide accurate predictive performance and design data to eliminate the need to always be conducting large full-scale hardware tests. We must be able to predict how propellants, structures, and components are going to respond under various environmental conditions imposed by the ambient surroundings and the combustion thermal environment during firing.

Advanced Front-End Propulsion....

State-of-the-Art

- MMIII & MX
- Prepackaged Liquid Bipropellant
- USN-Trident
- Fuel-Rich Solid Gas Generator

Technology

- Solid Staged Combustion
- Adv. Liquid Monoprop (Self-Pressurizing Hydrazine Blend)

Payoff

- 40% Weight Reduction Below Solid Gas Generator
- As Above Plus 60% Weight and 40% Volume Reduction for Hot Gas Pressurization of MX-Stg IV

Transition Targets

- Small/Advanced ICBM
- MX Stage IV Upgrade (Hot Gas Pressurization)

FIGURE 30

Ballistic Missile Service Life

Propellant Service Life....

State-of-the-Art

- Processing & Manufacturing Variables
  - Leading to Unexpected Motor Failure
  - Not Considered in Structural Analysis
- Little Interchange between Technologies and Manufacturers

Technology

- Identify and Control Critical Manufacturing Failure Modes
- Understand Effects of Ingredient Variables on Initial Motor Properties and Aging Process

Payoff

- Reproducible Propellants, Liners, Insulators, and Bond Systems
- Greater Motor Margins of Safety
- Effective, Timely Tech. Transfer

Transition Targets

- Ballistic Missile Office
- Designers and Manufacturers
- Ogden ALC

FIGURE 31

Multiple Application Technology....

OBJECTIVES:

- Foster and Establish Feasibility of Unique Propulsion Concepts
- Advance State-of-the-Art in Core Technologies Applicable to All Rockets

PAYOFFS:

- Revolutionary System Capabilities
- More Reliable and Maintainable
- Lower Initial & Replacement Costs

ACCOMPLISHMENTS:

- Non-Toxic B-52 Starter Cartridge Propellant Demonstrated
- Nitramine Burnrate Key Discovered
- Acoustic Instability Eliminated
- Surveillance Tools Transitioned

FUNDING (S×Millions):

PE	FY83	FY84	FY85
61101F	0.5	—	—
61102F	1.6	1.5	1.6
62302F	7.4	7.4	9.1

MILESTONES:

MILESTONES	QTR/FY
• Acoustic Emission NDT Demo	4/83
• Demo Solar Rocket	2/84
• Internal Plasticizer Demo	3/84
• MPD Steady State Demo	4/84
• Initiate Alternate Propulsion	1/85
• Space SRM Coning Eliminated	3/85

FIGURE 32

Multiple Application Technology....

What Is It?

- Fundamental | Chemistry, Physics, Mathematics > ENGINEERING TOOLS

Why is it Important?

- Lower Development Risk/Cost
  Provides Tech Base for Rocket Development
  Design it Right to Avoid Telling You How to Fix It

What Is the Status?

- Continual Improvement of
  - Predictive Tools
  - Barrier Busters

Measure of Success?

- Transition to Applications Development
  Problem Solving Tools Used

FIGURE 33

The propulsion implications in this thrust are driven by the fact that present chemical energy sources are approaching a limit. Future systems will require a higher energy density, consequently, new energy sources must be found. Therefore, we must evaluate revolutionary, unique propulsion concepts. Weapon systems users are continually expecting fewer propulsion problems, we must learn to design it right the first time. This means we need better performance prediction tools. Future conventional propulsion systems are expected to increase their performance. In the core technologies area we will synthesize advanced propellants and ingredients to achieve higher energy or to improve the quality of the combustion process. Combustion instability can cause performance loss, and in some cases, destruction of an entire motor or missile. We must be able to understand the combustion process so we are looking for ways to improve the quality and reduce the cost of combustion stability measurements. Future missile systems need to have a longer service life capability. Presently, service life prediction is an art and not a science. We need to develop means to predict and assess motor structure integrity to eliminate the present approach of having to remove missiles and physically take them apart to determine their acceptability.

The efforts in this thrust are grouped into four sub thrusts. The Advanced Propulsion Concepts sub thrust looks at radically new propulsion concepts such as solar power, magnetoplasmadynamic (MPD), pulsed inductive thruster (PIT) and novel launch techniques. Research in advanced energy generation and storage is continuing at a basic level. Better solid propellant processability, stability, lower ingredient costs, and improved physical properties are the goals of Propellant Chemistry sub thrust. The Combustion sub thrust is chiefly concerned with improved combustion efficiency and stability for both solid and liquid rocket motors. The mechanism and kinetics of the combustion process are examined and modeled; this provides methods for design improvements. Using the historical shelf-life data from operational missile motors the Motor Structural Integrity sub thrust investigates methodology for longer life solid rocket motors. This includes the propellant, case, liner, insulator and the interfaces between these materials.

b. Payoffs

New, better, and cheaper ways to provide rocket propulsion best describes the payoff of this major 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 propulsion concepts, to develop improved propellants for increased solid rocket performance, and to provide low risk, low cost propulsion concepts and approaches.

c. Accomplishments

Several technical accomplishments have been made in this major thrust; four are shown in Figure 32. A minimum smoke propellant has been developed for B-52 starter cartridges that is also significantly less corrosive and less toxic. Nitramine solid propellant burnrate control has been achieved through two separate investigations. These discoveries are key to the utilization of minimum smoke propellants in a wide variety of applications. Aerodynamic contouring of solid propellant grains was found to have a significant ballistic effect in eliminating combustion acoustic instability in solid motors. The vital and necessary surveillance technology to determine the useful life of the Peacekeeper missile has been transitioned to the Project Office. This technology circumvents extensive and expensive testing and the lack of predictive capability that was characteristic of the Minuteman surveillance program.

d. Milestones

Some of the significant milestones in this major thrust are listed in Figure 32. Acoustic Emission NDT is the culmination of six years of effort to design a portable tool for air-launch and ballistic missile motor quality inspection. This instrument is designed primarily for detection of flaws at the bond line in solid propellant motors but it is also capable of locating voids and cracks within the grain. It is being evaluated at the AFRPL with technology transfer to Ogden ALC scheduled for FY 84. The Solar Rocket Demonstration milestone will be the completion of our in-house program of evaluating a sub-scale solar rocket thruster. The system uses a six meter solar concentrator to evaluate the specific impulse and thermal efficiency of a one-pound thruster. An artist conception of the eventual space unit is seen in Figure 34. The theoretical performance values give a good indication why the Air Force is interested in the solar thermal concept. Originally funded by the Laboratory Director's discretionary funds (6.1), Internal Plasticizers is now ready for demonstration; this is scheduled for completion in the third quarter of FY 84. This program could solve the problem of migrating plasticizers which has caused service life problems with many solid rocket motors.

The second of our advanced concepts that shows great promise is the Magneto Plasma Dynamics (MPD) thruster. An actual firing of the breadboard unit (0.04 lbf) is shown in Figure 35. This unit has been demonstrated in pulse mode operations. In the fourth quarter of FY 84, we hope to demonstrate steady state operation of this unique and important thruster technology. Our AFOSR/AFRPL basic research effort is yielding still other advanced propulsion concepts of tremendous potential. We will initiate development of at least one of these alternate propulsion efforts in the first quarter of FY 85.

The recent failures of solid space motors has revealed some unique combustion problems heretofore not encountered. The Laboratory Director has initiated a program to define, examine, quantify and solve Solid Rocket Motor (SRM) Space Coning problems; we anticipate this will be completed in the third quarter of FY 85.

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Multiple Applications Technology

Advanced Concepts....

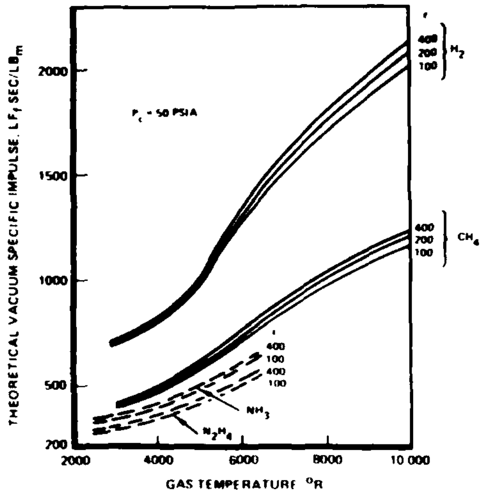

FIGURE 34

Advanced Propulsion Concepts

Magneto Plasma Dynamics....

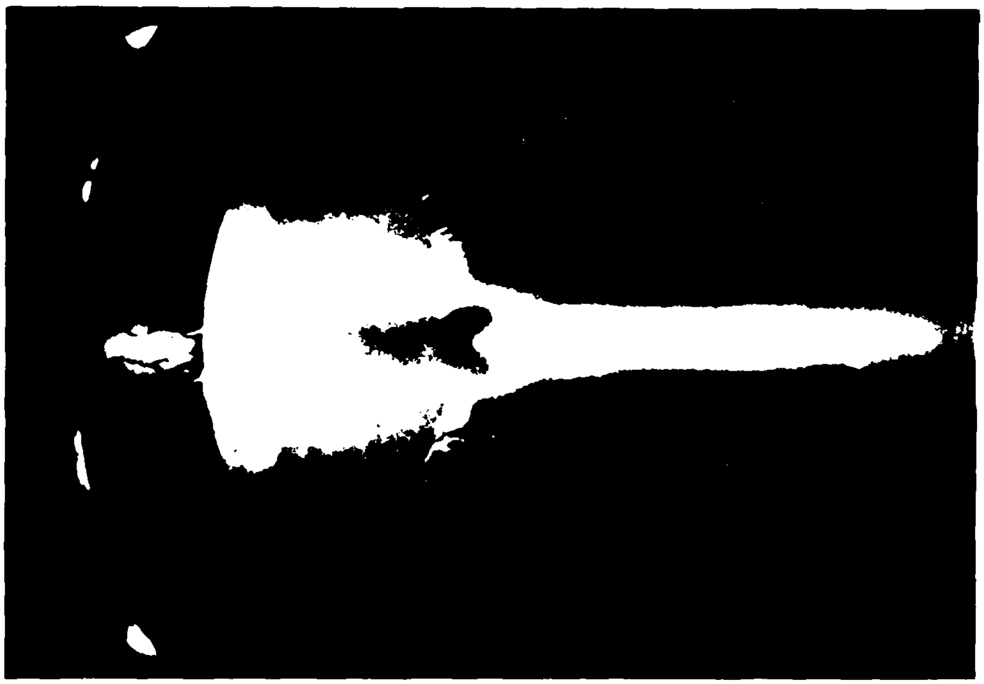

FIGURE 35

e. Funding

The table in Figure 32 shows funding we plan to apply to this thrust area. The Program Element 61101F monies are from the Laboratory Director's Fund. The 61102F monies are AFOSR research funds being applied to rocket propulsion goals. All of the exploratory development investigations are accomplished under Program Element 62302F, Project 5730.

f. Technical Opportunities

The nearest term advanced concept that we believe we can exploit is the solar rocket. Of course, our supporting core technologies are applicable to all future military systems using rocket propulsion.

ORGANIZATION/MANPOWER

The current AFRPL organization is shown in Figure 36. The Laboratory manpower consists of approximately 460 military and civilian scientific, engineering, administrative and support personnel.

FUNDS

The Laboratory manages approximately 50 million dollars per year of which about 60 percent is contracted with industry and universities for the development of rocket propulsion and related discipline technologies. These funds support basic research (6.1), exploratory development (6.2), and advanced development (6.3) programs. This total of funds includes all sources of resources including those provided by other services and other government agencies desiring our support.

FACILITIES

The AFRPL has been developed over the years into a research and development complex with a replacement value over $750,000,000, capable of full spectrum research and development of rocket propulsion systems and their associated propellants and components. The AFRPL is unique with the combined capability for research and development of all sizes of liquid or solid propulsion systems at sea level or simulated altitude. Our experimental capability spans the spectrum from millipound thrust satellite attitude control engines requiring very precise measurement to million-pound thrust solid rocket boosters. We have propellant synthesis facilities, electric propulsion laboratory, rocket component laboratory, motor/engine and integrated experimental system fabrication shops and a data processing and computer center. The rocket technology experimental complexes plus the supporting shops, storage and administrative facilities are shown pictorially in Figure 37.

Air Force Rocket Propulsion Laboratory

as of 1 September 1983

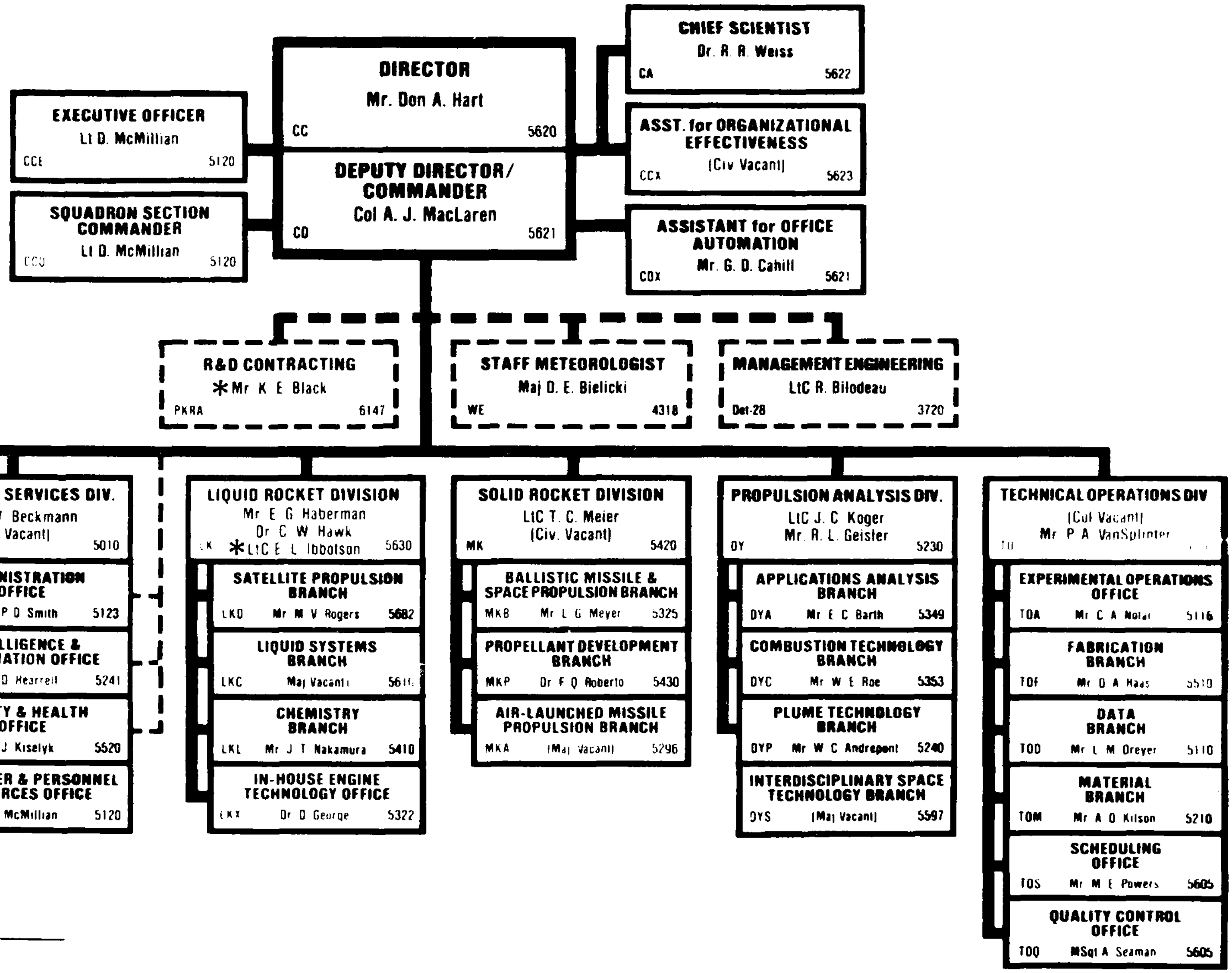

FIGURE 36

Approved: ______________

*Denotes a change from previous edition

EDWARDS AIR FORCE BASE, CA 93523
Autovon: 350-XXXX Commercial: (805) 277-XXXX

AIR FORCE ROCKET PROPULSION LABORATORY FACILITIES....

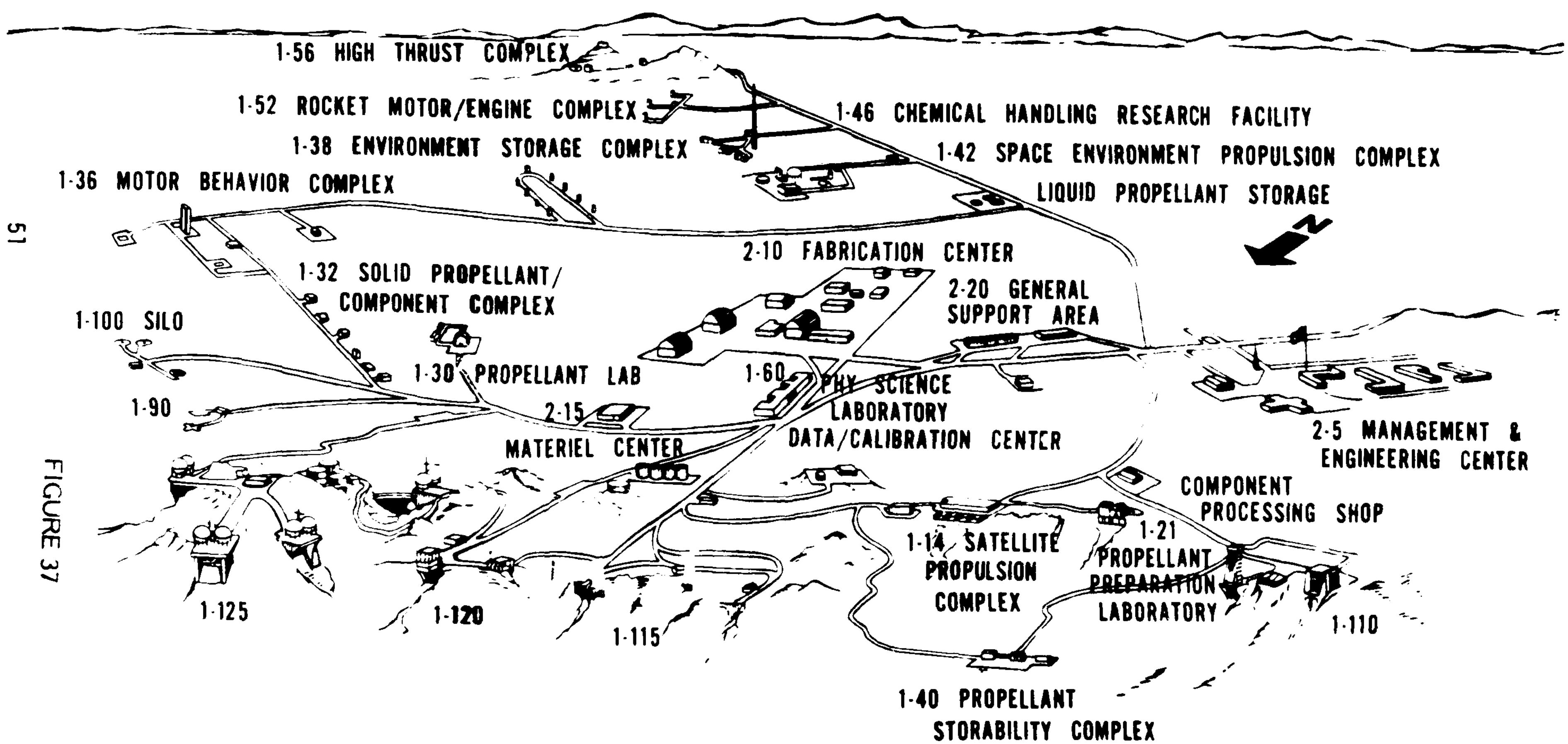

FIGURE 37

APPENDIX

FY 85 PROGRAM LISTING

PROGRAM DESCRIPTIONS

AIR FORCE ROCKET PROPULSION LABORATORY
SUMMARY OF FY 85 PROGRAM

NOTES:

1. This program listing is organized by:

   - Major Thrusts (MT) A, B, C, D and E

   - Clusters within each Major Thrust

   - Work Units

2. The funds shown are approximate levels from 6.1, 6.2 and 6.3 sources for all work units within each cluster. These include funds for supplies and equipment for in-house efforts but do not include in-house personnel costs.

3. The asterisk (*) indicates a new competitive contract in FY 85. The remainder of the work units are continuation of existing contracts, new selected source procurements or projects conducted in-house (designated I-H) or by another government organization.

MT-A, BALLISTIC MISSILE PROPULSION TECHNOLOGY

1. Ballistic Missile Service Life ($600K)

   *Structural Integrity Monitor
   Ballistic Missile Propellant Bonding Technology
   Humidity Aging Effects
   Ballistic Missile Propellant Service Life
   *Structural/Ballistics Interaction

2. Advanced Booster Technology ($1,600K)

   Multi-Mission Missile Propellant
   Composite Polar Boss Development
   Advanced Composite Case Material Evaluation
   Integrated Stage Propulsion Concept Investigation
   *Full-Scale Wound Insulator Demonstration
   Composite Case In-House Technology (IH)
   Integrated EEC Concepts

3. Nozzle and Exit Cone Technology ($1,700K)

   Innovative Nozzle Designs (IH)
   *Mechanics of Involute Failure
   *Innovative Nozzle Construction
   Carbon/Carbon Component Laboratory Investigations (IH)
   Carbon/Carbon Exit Cone Technology (IH)
   Improved Carbon/Carbon Fiber/Matrix (IH)
   Carbon/Carbon Nozzle Materials Characterization
   *Quality Control Test Methods Improvement

4. Advanced Front-end Propulsion ($500K)

   Solid Staged Combustion Propulsion
   Advanced Front-end Propulsion Technology
   Propellant Tank Storability and Expulsion Investigation

MT-B, AIR-LAUNCHED MISSILE PROPULSION TECHNOLOGY

1. Low Signature Motors ($1,000K)

   Nitro Ingredient Production/Propellant Demonstration
   Minimum Signature Propellant Demonstration
   Class 1.3 Minimum Smoke Propellant Development
   Develop Reduced Smoke/Minimum Smoke Propellants (IH)
   *Burn Rate Control of Minimum Smoke Propellant
   Motor Handling Procedures and Implementation
   *Low Cost Minimum Smoke Propellant Igniter
   Minimum Smoke Service Life

2. Plume Signature ($730K)

*Standard Plume Flow Model Update
Standard Plume Flow Model Validation Experiments
Gas Particle/Turbulence Interactions
*Reacting Turbulent Mixing
Solid Rocket Motor Diagnostics
IR Optical Properties
IR/UV Data Assessment/Compilation
Air-Launched Missile Plume Radar Cross-section Assessment (IH)

3. Improved Performance Motors ($3,800K)

Composite Case Durability Investigation
High Temperature Plastic Laminate Evaluation
Composite Case Optimization Code
Composite Attachments for Air-Launched Motors
Advanced Air-Launched Motor (6.3 Program)
Liner Barrier Coating Technology
*Metal Matrix Materials for Rocket Motor Application
*Cumulative Damage and Repair Assessment for Composite Cases
*Unique (Non-Circular) Rocket Motor Case Demo
High Pressure Propellant Characterization
*High Performance High Burn Rate Propellant Investigation
*Service Life Verification Program
*Rocket Motor Seals
Low Cost Anti-Corrosion Program

4. Propulsion Flexibility ($700K)

Pulse Motor Thermal Barrier Improvement
*Variable Thrust Solid Rocket Motor
Laser Initiated Arm-Fire-Device

5. Air-Launched Missile Propulsion Analyses ($200K)

Air-Launched Missile Propulsion Applications (IH)
System Level Air-to-Air Performance Study Support

MT-C, SPACE SYSTEMS PROPULSION TECHNOLOGY

1. Satellite Propulsion ($1,000K)

Satellite Oxidizer Feed System (IH)
Automatic Isolation System Space Demonstration
*Low Cost Overwrap Composite Tank Fabrication
Reuse Component Development
*Large Space System Reaction Control System Design Study
Pulse Plasma Thruster High Energy Density Capacitor Development
Capacitor Health Diagnostic Investigation

2. Special Mission Propulsion ($1,600)

Advanced Propulsion for Space Sortie Vehicle
Cluster Engine Technology (IH)
High Temperature Turbine Investigation
*High Temperature Turbine Demonstration
*Engine-Vehicle Integration
*Lightweight Engine Components
*Reduction of Propellant Residuals
*Reusable Propellant Tanks
*Cryogenic Auxiliary Propulsion System Feed System

3. Orbit Transfer and Maneuvering Propulsion ($7,300K)

Modular/Storable Propulsion System Demonstration (6.3 Program)
Advanced Spacecraft Feed System
Storable Advanced Rocket Technology Program (IH)
*Advanced Regeneratively Cooled Thrust Chambers
*Low Cost Titanium Tanks
Inert Corrosion/Erosion Measurement Device (IH)
*Step Thrust Throttling Modular Engine
*Cryogenic Auxiliary Control System Integration Study
*Cryogenic Propellant Abort Dump He/Gas Generator Study
Compact LO_2 Feed System Technology
Compact Cryogenic Feed System Demonstration (6.3 Program)
*Low Thrust Cryogenic Engine Technology
Small Cryogenic Engine Boundary Layer Loss Investigation (IH)
Long-Term Cryogenic Propellant Storage In-Space

4. Space Motors ($300K)

Consumable Wafer Igniter
Space Motor Surveillance Techniques (IH)
Space Storage Investigation
Advanced EEC Deployment System

5. Plumes ($700K)

Plume/Missile Body Interaction
Clustered Nozzle Flowfield
Flowfield Review/Analysis
JANNAF Radiation Model Maintenance
Plume Signature Model Verification
Collision Quenching Rates
Composite High Altitude IR Model
*Fuel Venting Modelling

6. Space Systems Propulsion Analysis ($700K)

Expanded Liquid Engine Simulator Code
Space Defense Investigation
*Maneuvering Propulsion System Study

MT-D, MULTIPLE APPLICATIONS TECHNOLOGY

1. Advanced Propulsion Concepts ($1,550K)

Solar Rocket Development
Coherent Injector Spray Characterization (IH)
Pulsed Inductive Thruster Component Technology
*Pulsed Gas Electric Thruster Valve Development
Establishment of MPD Performance (IH)
Alternate Near-Term Electric Propulsion Concept Evaluation (IH)
Revolutionary Propulsive Energy Concept Evaluation
Have Sting
Electric Propulsion Performance Assessment
*Electric Propulsion Mission Requirements
Plasma Dynamics of an Arc Driven, Electromagnetic Launcher (IH)
*Advanced Pulsed Plasma Thruster Concepts

2. Propellant Fundamentals ($800K)

Polymer Synthesis and Binder Concepts (IH)
Mechanistic Combustion of Isotopically Labeled Propellant Ingredients (IH)
New Synthetic Techniques for Advanced Propellant Ingredients (IH)
Initial Thermochemical Decomposition Mechanisms of Energetic Ingredients (IH)
Solid Propellant Binder Prepolymer Characterization
Chemical Ingredient Studies (IH)
N_2O_4 Cleaning Process
*Critical Evaluation of Propellant Ingredient Data

3. Improved Solid Propellants ($1,300K)

*Difunctional Binder Development
Solid Propellant Ingredient Study (IH)
*Antioxidant Effects on Propellant Properties
Insuliner Technology
Stabilized Ammonium Nitrate
Propellant Processing and Scale-up
GAP Propellant for Advanced Missiles
Modification of Propellant Binder Network

4. Combustion ($2,200K)

Stability Analysis (IH)
Advanced Burner Applications (IH)
Acoustic-Mean Flow-Combustion Interaction (IH)
*Velocity Coupling
Acoustics With Mean Flow
High Frequency Response Investigation
Non-Linear Stability Validation
Fluid Dynamic-Combustion Interactions (IH)
Minimum Smoke Burnrate Mechanisms
Temperature Sensitivity Technology

*Temperature Sensitivity Verification
*Propellant Flow Effects on Ballistics
Propellant Ballistics Evaluation (IH)
Particle/Droplet Combustion at High Pressure (IH)
Automated Holographic Combustion Data Retrieval
Combustion Process Visualization
Agglomerate Breakup Control (IH)
Efficient Metal Combustion (IH)
Internal Flow Field Investigation
Gas Sloshing Investigation
Motor Prediction Methodology (IH)
Hot Gas Sloshing Measurements
Physics of Nozzle and Plume Flows (IH)
Combustion Mechanisms (IH)
Flame Suppression Kinetics (IH)
*Improved Standard Liquid Performance Prediction
*Spray Field and Reactive Stream Modelling
*Droplet Mechanisms in Oscillatory Flow

5. Motor Structural Integrity ($1,200K)

Solid Propellant Mechanical Behavior (IH)
Structural Failure Investigation (IH)
Material Mechanics Research (IH)
Solid Propellant Aging (IH)
TEXGAP 84
*Non-Linear Constitutive Theory Transition
Composite Case/Grain Behavior
Structural Integrity Technical Assessment
Chemiluminescence for Aging
Propellant Strain Measurement Technology
*Chemical Migration Reaction Models
Propellant Aging Research

6. Materials Handling ($650K)

Post Accident Procedures for Chemicals and Propellants
*Remote Transfer of Hazardous Materials
Propellant Vapor Suppressant/Chemical Specifications (IH)
Space Propulsion Hazards Analysis Guide
Damaged Solid Propellant Disposal Guide

MT-E, INTER-DISCIPLINARY SPACE TECHNOLOGY ($3,000K)

*Contamination Design Criteria
*Advanced CONTAM Model Improvement
Surface Effects Evaluation
Pulsed Plasma System Interaction Study
Develop Electric Thruster Flowfield Diagnostic Technique
Contamination Data Base Management
HAVE BUSK A Demonstration (IH)
*HAVE BUSK A Concept Space Experiment Design
HAVE BUSK B Demonstration Program

Large Space Structure Deployment Dynamics
Flexing Structure Control (IH)
Large Space System Design (IH)
ADA-Based Real Time Control Software
Structure Control Demonstrations (IH)
*Optical Test Bed
Advanced Control Concepts
Micro Electronic Mirror Control (IH)
Ultralight Reflectors
Ground Station Demonstration of Self Organized Failure Prediction
*Satellite Acoustic Sensor Study
Robotics Function Assessment (IH)
Liquid Droplet Radiator Component Dev
Liquid Droplet Radiator Systems Investigation
*Liquid Droplet Radiator Feasibility Demonstration
*Direct Contact Heat Exchanger for Space
*HAVE BUSK C Enhancement Program
HAVE BUSK D Enhancement Program
HAVE BUSK E Program

FY 85 PLANNED NEW COMPETITIVE CONTRACTS
PROGRAM DESCRIPTIONS

1. TITLE: STRUCTURAL INTEGRITY MONITOR

OBJECTIVE: To develop and demonstrate a prototype damage event detection system for advanced ballistic missile systems.

PAYOFF: A passive damage monitor system for in-field use. (Wooden Round Concept)

APPROACH: Acoustical technology will be utilized in the design and development of the monitoring system. Attention will be payed to the number and placement of the acoustical emission transducers to observe the critical areas of rocket motors. System portability and durability will be factors in design, this being influenced by the basing mode. The developed device will be demonstrated on a full-scale motor.

SCHEDULE: Start Work: Apr 85
Program Duration: 36 months

2. TITLE: STRUCTURAL/BALLISTICS INTERACTION

OBJECTIVE: To relate structural failure to mission/ballistic failure.

PAYOFF: Translation of structural analysis margins of safety into practical user/SPO oriented results; i.e., mission reliability.

APPROACH: This program will provide the technology needed to apply damage tolerant design techniques to advanced strategic missile motor structural integrity and service life analyses and utilize the ultimate motor service life. Fracture mechanics has been successful in predicting growth of pre-existing flaws in solid propellant grains under long-term and low rate loading conditions. The fracture mechanics approach will be extended to handle flaw initiation, ignition of crack surfaces, and ballistic-structural interaction in motors with crack or flaws. The effort will include refinement of flaw initiation, crack burning and coupled ballistic/structural modelling techniques. Experiments will be conducted to characterize burning/fracture interaction in propellant specimens, and analog motor firings will be performed to develop data and verify analytical predictions of motor ballistic failure.

SCHEDULE: Start Work: Jan 85
Program Duration: 36 months

3. TITLE: FULL SCALE WOUND INSULATOR DEMONSTRATION

OBJECTIVE: Design, and demonstration of a wound case insulator for application to solid propellant rocket motors which utilize a fiber composite motor case.

PAYOFF: Significant reduction in insulator cost without loss in motor performance, shorter tooling lead time, and improved insulator design flexibility.

APPROACH: Elastomeric insulators are used to thermally protect the motor case of a solid rocket motor. These insulators are manufactured using expensive hand-layup procedures. The tooling is costly, requires long lead time, and any design change is expensive and time consuming. The cost of the insulator can be reduced significantly by winding the insulator directly onto the case mandrel. Ideally the fiber composite motor case would be wound directly onto the insulated mandrel, and both insulator and case would be cured simultaneously. In addition, this concept provides design flexibility and can potentially improve motor performance. This program will be accomplished in four phases. Under Phase I alternate wound insulator approaches will be evaluated against a realistic baseline solid motor design. Candidate concepts will include the Filament Wound Insulator (FWI) and the Wound Elastomeric Insulator (WEI) concepts evaluated under AFRPL contracts. Under Phase II, a detailed insulator design incorporating the selected concept from Phase I will be accomplished. Limited processing studies and bench tests will be conducted to select the best material and process for the baseline motor design. Under Phase III, the concept will be demonstrated on full-scale motor cases. Several cases will be burst to evaluate the design. Under Phase IV, several motors will be fabricated and fired to verify the insulator performance.

SCHEDULE: Start Work: Sep 85
Program Duration: 25 months

4. TITLE: MECHANICS OF INVOLUTE FAILURE

OBJECTIVE: Develop a first order model that relates how the failure strengths of exit cones change due to the interaction of varying combinations of multiaxial loads.

PAYOFF: Fewer failures, lower net unit cost, fewer program slips.

APPROACH: The specific issue to be addressed is the effect of multiaxial loads on the failure mode excited and the effective strength in an involute exit cone. The main focus will be on the effect of crossply normal stresses on the interlaminar shear strength. As an example, consider a case of two blocks of wood sitting one on top of the other with no adhesive between them. The amount of force which can be applied without pulling the blocks apart is very low and depends solely on friction. If friction is increased by applying a load then a larger force can be developed. A similar case for the shear carrying capacity between the plys of an involute exit cone can be described. This program will examine the effects of loads acting in combination on the strengths of involute materials. The program will be composed of three tasks. The first task would review the existing base of material characterization data and exit cone tests and formulate a plausable hypothesis to account for the materials behavior and conditions which induced failure. Task II would define and conduct laboratory tests on flat and subscale involute parts to examine the validity of the hypothesis. This test series would include approximately 150 lab scale tests to failure. The final task would take the hypothesis and test data and define a failure criteria for involute structures subjected to combined loads.

SCHEDULE: Start Work: Jun 84
Program Duration: 30 months

5. TITLE: INNOVATIVE NOZZLE CONSTRUCTION

OBJECTIVE: Demonstrate successful construction of the nozzle design developed during the in-house Innovative Nozzle Design Program.

PAYOFF: Better solid rocket nozzles that exhibit controlled recession, contain fewer parts, are easier to manufacture, and are lower in cost.

APPROACH: This program will consider segmented, braided, radially pierced, woven, and sandwiched construction of solid rocket nozzles. Nozzles will be manufactured, pre-test characterized and performanced analyzed.

SCHEDULE: Start Work: Oct 84
Program Duration: 36 months

6. TITLE: QUALITY CONTROL TEST METHODS IMPROVEMENT

OBJECTIVE: Design, develop and demonstrate useful techniques to define material defects and the reliability of C-C exit cones.

PAYOFF: Increase capability of NDE methods for detecting material defects and increased reliability of exit cones in their service life.

APPROACH: Conduct a trade study of known NDE concepts. Design, analyze, fabricate and demonstrate the concepts with government furnished exit cones. Both partially processed and fully processed C-C exit cones will be subjected to the recommended Q.C. tests. Establish interpretation of results and cost factors associated with such techniques.

SCHEDULE: Start Work: Oct 84
Program Duration: 30 months

7. TITLE: BURNRATE CONTROL OF MINIMUM SMOKE PROPELLANT

OBJECTIVE: To demonstrate minimum smoke propellants with extended burning rates.

PAYOFF: Tailorability of the "natural" burning rate of HMX and RDX propellants.

APPROACH: Based on the technology developed in on-going Nitramine combustion programs, propellants will be formulated that demonstrate improved ballistics (various burning rates and reduced slope). Experimental motors will be cast to determine ballistic properties.

SCHEDULE: Start Work: Oct 84
Program Duration: 30 months

8. TITLE: LOW COST MINIMUM SMOKE IGNITER

OBJECTIVE: Reduce the cost for igniters to be used in minimum smoke and reduced smoke rocket motors.

PAYOFF: Reduced production cost for minimum smoke and reduced smoke rocket motors.

APPROACH: This will be a two-phase effort. Phase I will involve igniter propellant development. The objective is to develop minimum smoke propellants with suitable physical, ignitability, ballistic, and hazard characteristics for use in igniters as $BKNO_3$ is currently being used. Phase II will involve igniter testing at high and low temperatures and altitude conditions. Two motors will be tested to verify the motor ignition characteristics.

SCHEDULE: Start Work: Apr 85
Program Duration: 15 months

9. TITLE: STANDARD PLUME FLOW MODEL UPDATE

OBJECTIVE: Provide state-of-the-art tools for plume analysis by incorporating new routines in existing computer codes.

PAYOFF: Reliable signature models for low IR propellant development sensor development (Talon gold, Teal Ruby) threat analysis and missile system design.

APPROACH: Use the results from various current programs in turbulent mixing, base effects and two phase flow modeling to update the standard government/industry model to do state-of-the-art predictions.

SCHEDULE: Start Work: Oct 84
Program Duration: 48 months

10. TITLE: REACTING TURBULENT MIXING

OBJECTIVE: Validate the improved plume turbulent mixing and afterburning models against controlled data base for coflowing supersonic streams with simple chemistry.

PAYOFF: This work supports Space Division's development of advanced missile surveillance sensors. This work provides prerequisite modeling information in order to obtain accuracies better than a factor-of-two.

APPROACH: Design a set of experiments for well characterized, supersonic reacting gas systems and establish a data base for axisymmetric reacting shear layer flows. Perform calculations using elements of the Standardize Plume Flowfield computer code using the turbulence models established during the Non-Reacting Turbulent Mixing Program and make comparisons with the data base. Determine effects of reaction energy release on turbulent mixing. Develop a model for turbulent reactive mixing.

SCHEDULE: Start Work: Apr 85
Program Duration: 30 months

11. TITLE: METAL MATRIX MATERIALS FOR ROCKET MOTOR APPLICATIONS

OBJECTIVE: Evaluate weight and cost savings associated with the use of metal matrix materials for typical rocket motors while maintaining comparable strength properties to metals.

PAYOFF: Data from flat plate test samples has shown metal matrix materials to be lower in weight by 10 - 20 percent and comparable in strength (within 5 percent) to metals that are now being used on missiles. With the users hesitant to use composite materials such as graphite, kevlar or hybrids for use as the rocket case materials, metal matrix materials would provide an option for use that would be lower in weight and cheaper to manufacture than if metals such as D6AC or 4130 steel were used. A goal of 20 - 30 percent weight savings and comparable strengths to metals is set for the program.

APPROACH: Conduct a literature search to find potential materials applicable to rocket case designs whether ballistic, air-launched, or space application. Establish a matrix of potential metal matrix materials and evaluate feasibility of each material under the listed applications. Manufacture subscale bottles for material evaluation. Test promising materials in analog test vehicles to determine integrity of the article when subjected to environments typical of air-launched, ballistic and space missiles. Conduct a review of data to determine potential weight savings and strengths of the materials. Concentrate on durability/reliability testing of the analogs. Scale-up to full-scale, one for each area (air-launched, ballistic, and space) and conduct structural (including vibration) and thermal testing of each full-scale article. Include evaluation of impact skirts, lugs, polar bosses, etc., have on the use of these materials.

SCHEDULE: Start Work: Jan 85
Program Duration: 27 months

12. TITLE: CUMULATIVE DAMAGE AND REPAIR ASSESSMENT FOR COMPOSITE CASES

OBJECTIVE: Predict service life expectancy of a typical air-launched composite case when subjected to real-life environment loading. Identify methods for repairing damaged composite structures as well as characterization of the damage.

PAYOFF: Knowing the service life capability of composite cases will allow for a better technology per capital invested. There has been little service life prediction of composite cases unlike that which has occurred for propellants. In addition, little emphasis has been made on size and types of defects in the composite and the methods for repairing these composites. This program will generate initial characterization of composite defects and their repairability.

APPROACH: Evaluate the aircraft industry data in the area of cumulative damage to see what data is transferable for use on this program. Select a typical design (JTACMS, AASM, ASAT, or BIM) and generate life cycle thermal and structural loading seen on the motor. Evaluate feasibility of cumulative damage assessment in analogs and full-scale motors. Build NOL rings and evaluate design under service life loading. Scale up to motor size and perform service life prediction. Assess relation between cumulative damage assessment on design selected and typical rocket designs. In subscale and analog size articles (10 - 20 inches) characterize defect size, quality, and type (i.e. damage) to determine integrity of part. Determine repair techniques for composite case application (both in the field and in the shop type repairs) and feasibility of each repair technique. Assess techniques as applicable to air-launched, ballistic, and space composite case.

SCHEDULE: Start Work: May 85
Program Duration: 27 months

13. TITLE: UNIQUE (NON-CIRCULAR) ROCKET MOTOR CASE DEMONSTRATION

OBJECTIVE: Evaluate the benefit of an aerodynamic shaped non-circular motor case for air-launched applications. Demonstrate strength of chosen designs.

PAYOFF: Improve range of boost-lift-glide vehicles and improve loading efficiency for rotary launcher on B-1B, B-52 or any launch platform.

APPROACH: Perform tradeoff studies comparing range increase of boost-lift-glide missile (20 in. cross-section approx.) with a missile powered by a circular case motor. Studies will include consideration of structural soundness, need of internal support, ability of the structure to maintain shape using metal and filament materials. Nozzle design will be included. Design and construct six each of the two most promising case designs in flightweight configuration. Burst test two of each design. Perform eject tests of two of each case design simulating 22,000 lbs dynamic load in 64 milliseconds. Pressure test two of each to demonstrate dimensional stability (without propellant). Using well-characterized ultra-high strain capable propellant, demonstrate case (two of each design) dimensional stability and propellant survivability by pressurizing at -65°F and +145°F.

SCHEDULE: Start Work: Jul 85
Program Duration: 24 months

14. TITLE: HIGH PERFORMANCE HIGH BURNRATE PROPELLANT INVESTIGATION

OBJECTIVE: To establish a 2.5 ips @ 2,000 psi burn rate propellant as on-the-shelf, with a stable catalyst in a Class 1.3 system.

PAYOFF: Stable catalyst propellant (non-migrative) for future air-to-surface type missiles.

APPROACH: Apply the best burn rate additive from previous AFRPL Solid Ferrocene and Copper burnrate catalyst programs to an 88 percent solids HTPB propellant. Requirements for SRAM will be used as typical of the A/L environment. A Dissect Test Vehicle (DTV) will also be cast and tested to check bondline properties (ballistic and mechanical) and flow characteristics.

SCHEDULE: Start Work: Jul 85
Program Duration: 30 months

15. TITLE: SERVICE LIFE VERIFICATION PROGRAM

OBJECTIVE: Establish statistical and technical guidelines for an integrated, cost effective service life verification program for air-launched rocket motors.

PAYOFF: Reduction in level of effort and greater technical reliability in development service life testing.

APPROACH: Each year more and more physical and chemical propellant tests were required to develop an air-launched rocket motor. This program will be a paper study using available data to determine just how much testing is required to obtain credible service life and structural integrity estimates. All aspects of physical and chemical propellant properties testing from number of dogbones pulled to number of motors tested will be considered. This study will involve statistical considerations, vehicle/sample manufacturing and testing costs, and data applicability needs to provide overall guidelines for typical motor types and uses.

SCHEDULE: Start Work: Jan 85
Program Duration: 15 months

16. TITLE: ROCKET MOTOR SEALS

OBJECTIVE: Develop a handbook to provide guidance in design of rocket motor seals (o-rings, omni-seals, etc.).

PAYOFF: Reduce the occurrence of motor (and missile) failure due to seal leakage.

APPROACH: The contractor shall conduct a review of available literature on seal designs. This data will be assessed for its applicability to rocket motor design. Extensive bench testing will be conducted to evaluate various seal designs. The contractor shall write a handbook on how seals should be designed for rocket motors.

SCHEDULE: Start Work: Aug 85
Program Duration: 18 months

17. TITLE: VARIABLE THRUST SOLID ROCKET MOTOR

OBJECTIVE: Demonstrate a unique energy management system using a pintle nozzle and a temperature compensation controller for thrust modulation.

PAYOFF: Complete control of missile thrust to obtain optimum energy management.

APPROACH: Perform mission studies to describe the most desired use of energy management in the Conventional Standoff weapon size. Evaluate various nozzle concepts from the Advanced Air-Launched Pintle Nozzle Program, AFRPL-TR-81-39, with temperature compensation control for maximum nozzle efficiency and motor performonce increases. Integrate the most advantageous nozzle concepts with a complete motor design (7 - 18 inch diameter). Demonstrate critical components and materials through component testing. Fabricate and test five full-scale motors at air launch temperature conditions (-65 to +145^{o}F). If possible a high burn rate/low slope propellant will be used as an end burner.

SCHEDULE: Start Work: Sep 85
Program Duration: 30 months

18. TITLE: LOW COST OVERWRAP COMPOSITE TANK FABRICATION

OBJECTIVE: Demonstrate the use of composite overwrap tanks as a low cost approach to manufacturing satellite propellant tanks and show propellant compatibility with N_2O_4 and MMH.

PAYOFF: Provide tanks lighter than aluminum while not making use of the expensive forge and machine manufacturing technique of strategic Ti-6V-4Al. Also, develop a tank that can be easily scaled in size to provide future options for large pressure fed space systems.

APPROACH: Tank designs will be supplied which represent satellite tank configurations. Analyses will be conducted to define materials, tank dimensions and wrapping patterns. Testing will be conducted to insure structural adequacy, mass fraction, and cost.

SCHEDULE: Start Work: Oct 84
Program Duration: 30 months

19. TITLE: LARGE SPACE SYSTEM REACTION CONTROL SYSTEM DESIGN STUDY

OBJECTIVE: Develop and demonstrate reaction control system capabilities necessary to provide the required control authority for Large Space Systems (LSS).

PAYOFF: The results of this program will provide the demonstrated capability of critical advanced RCS components for future USAF missions such as Space-Based Radar.

APPROACH: The USAF system technologists and designers must be prepared for the operational use of high area/mass ratio and high inertia satellites (i.e., space based radar and space-based laser). The control authority requirements of these large systems vary depending upon the mission, the type structure, the orbital altitude, etc. The preceding study will have identified critical factors for control. This program will identify the critical hardware required to implement the control laws in order to meet mission objectives. Detailed studies and tradeoff analyses will be conducted based upon the results of the Flexing Structure Space Systems Control program to identify and design RCS components critical to LSS attitude control.

SCHEDULE: Start Work: Oct 84
Program Duration: 21 months

20. TITLE: CAPACITOR HEALTH DIAGNOSTIC INVESTIGATION

OBJECTIVE: Investigate the use of acoustic sensors to detect incipient failure in high power capacitors used in electric satellite propulsion.

PAYOFF: Avoid capacitor failures and thereby increase reliability and avoid damage to the propulsion system.

APPROACH: Experiments shall be conducted to detect, analyze, and characterize the high frequency acoustic signals emitted by high power capacitors as they approach failure. The data shall be thoroughly analyzed for frequency signature of incipient capacitor failure. Acoustic sensors would then be a viable inflight monitoring system.

SCHEDULE: Start Work: Apr 85
Program Duration: 12 months

21. TITLE: HIGH TEMPERATURE TURBINE DEMONSTRATION

OBJECTIVE: Demonstrate capability of increasing turbine component life by at least 400 percent over current designs for engines of special mission vehicles.

PAYOFF: Current state-of-the-art staged combustion turbine blades are life limited by thermal fatigue to 13 starts. With active film cooling, this number can be increased to Space Shuttle baseline of 55 missions or more without sacrificing performance. Potential application of ceramic materials to these components will enable the long life along with increased performance due to eliminating the cooling flow.

APPROACH: Technology and materials developed in previous AFRPL programs will be used to design and fabricate a sub-scale turbine assembly. Rotating tests with cold gases will verify aerodynamic efficiencies as established in stationary component experiments in the previous turbine program. Tests with a representative hot gas drive source will demonstrate the load, thermal fatigue and thermal shock capability of the selected concept.

SCHEDULE: Start Work: Oct 84
Program Duration: 30 months

22. TITLE: ENGINE-VEHICLE INTEGRATION DEMONSTRATION

OBJECTIVE: Accomplish flightweight design of altitude compensating nozzle for engines of advanced military launch vehicle, and verify specific impulse gain, weight and fabricability.

PAYOFF: Typical engines with bell nozzles considered for military launch vehicles use an altitude compensating nozzle to increase the effective expansion ratio and gain specific impulse at altitude. The estimated 10 sec. gain accounts for over half the projected payload capability for a typical vehicle. This program will establish confidence in the specific impulse gain and weight of the selected nozzle concept, thus accomplishing a significant portion of the verification of the capability of typical vehicle concepts.

APPROACH: Engine cycle studies will establish the cooling method and approach to applying an altitude compen[illegible]ing nozzle into an engine. In addition to considering mechanical translation of a two-position nozzle, aerodynamic approaches to an effective increase of expansion ratio within a fixed nozzle will be evaluated. Potential approaches include controlled flow separation within a nozzle at low altitude. Another potential approach will be integration of the nozzle such that part of the vehicle surface becomes an altitude compensating nozzle. Cold flow tests of sub-scale nozzles will evaluate these approaches and define the specific impulse gain for selected contours. A flightweight design will be accomplished for the selected approach. A fabrication concept will be selected and demonstrated at sub-scale or in segments of the full-scale nozzle. Hardware will be fabricated for tests at simulated altitude in a test bed engine.

SCHEDULE: Start Work: Jan 85
Program Duration: 54 months

23. TITLE: LIGHTWEIGHT ENGINE COMPONENTS

OBJECTIVE: Demonstrate weight reduction in structural components of high pressure liquid propellant engines through the use of advanced materials and fabrication techniques.

PAYOFF: Advanced material concepts and fabrication techniques are projected to allow engine weight reductions of 15 to 25 percent, or a savings in the range of 1,500 lb of inert weight for typical vehicles. This can be translated directly into payload gain providing a 40 percent increase above current technology capability.

APPROACH: Reductions of engine inert weight and increases of engine thrust/weight ratios are extremely important to the practicality of the vehicles considered for Advanced Military Spaceflight Capability. Advanced materials such as composites and fabrication techniques such as superplastic forming will be evaluated for application to structural components, housing and pressure shells. Selected engine components, or representative sections of components will be fabricated and subjected to appropriate structural and thermal loading to demonstrate suitability of the selected material or technique. Full size components will be provided for demonstration on an engine test bed.

SCHEDULE: Start Work: Mar 85
Program Duration: 66 months

24. TITLE: REDUCTION OF PROPELLANT RESIDUALS

OBJECTIVE: Demonstrate propellant loading accuracies on the order of 0.2 percent for a cryogenic propellant tank in the horizontal position with a loading time of less than two hours, and demonstrate outflow with a residual of less than 0.3 percent.

PAYOFF: Allows vehicle to be designed for minimum propellant residual, thus allowing payload goals of 5,000 to 10,000 lb to be met in the typical concepts considered for military launch vehicles such as the Advanced Military Spaceflight Capability (AMSC). Also allows gross weight reductions of up to 5 percent, which is extremely critical to the weight limited air-launched concept.

APPROACH; Analyses and scale model loading and outflow tests will be conducted to develop liquid level sensors, vent configurations, and outlet shapes. These techniques will be demonstrated in larger size tanks representative of the class of vehicles being considered. Loading techniques will be developed to allow fill of a horizontal tank in less than two hours. Propellant acquisition devices will also be developed to allow engine start in a zero or negative-g condition.

SCHEDULE: Start Work: Nov 84
Program duration: 60 months

25. TITLE: REUSABLE PROPELLANT TANKS

OBJECTIVE: Develop and demonstrate the technology required for lightweight internal tanks to contain cryogenic propellants for reusable military launch vehicles.

PAYOFF: The application of advanced material and fabrication techniques to cryogenic propellant tanks will reduce the gross launch weight by to 25 percent as compared to current technology. This will allow the payloads in the 5,000 to 20,000 lb class to be achieved with acceptable launch weight, which is particularly critical for weight-limited air-launched systems. The desired vehicle turnaround times of 24 hours or less will also be facilitated by the multi-use capability and the availability of fast post-mission inspection and refurbishment techniques.

APPROACH: The propellant tank material and fabrication approach will be selected from vehicle concept definition studies expected to be conducted under Program Element 63406F in FY 84 and 85. Fabrication development will proceed from small scale tanks or panels to representative full size tanks. Emphasis will also be placed on reusable insulation for the cryogenic propellants. Fast post-mission inspection and refurbishment techniques will be developed. Mission cycle capability will be demonstrated through the application of structural and thermal loads.

SCHEDULE: Start Work: Mar 85
Program Duration: 54 months

26. TITLE: CRYOGENIC AUXILIARY PROPULSION SYSTEM FEED SYSTEM

OBJECTIVE: Demonstrate critical technology for the propellant feed system of a cryogenic O_2/H_2 auxiliary propulsion system (APS) to provide orbital maneuvering and reaction control for special mission launch vehicles.

PAYOFF: Oxygen and hydrogen propellants will eliminate the pre-flight and post-flight servicing problems caused by the toxic and corrosive storable propellants typically used for auxiliary propulsion. The reduction in maintenance time and propellant logistics will substantially reduce operating costs and improve availability for on-demand missions.

APPROACH: Cryogenic auxiliary propulsion systems have been selected in the advanced technology special mission vehicle studies, such as the AMSC Technology Identification completed in March 1983. For this program, a feed system configuration will be selected after design definition studies in conjunction with the vehicle concept selection on PE 63406F. Tradeoffs will include separate APS tanks vs integration with the main propellant supply and gaseous vs liquid feed system. A breadboard feed system including pumps, heat exchangers and accumulators will be assembled and demonstrated to provide propellants for thruster operation. Critical items include zero-g propellant acquisition and quantity gauging.

SCHEDULE Start Work: Mar 85
Program Duration: 66 months

27. TITLE: ADVANCED REGENERATIVELY COOLED THRUST CHAMBERS

OBJECTIVE: To develop and demonstrate advanced regen-cooled chambers for storable propellant liquid rocket engines.

PAYOFF: The results of this program will provide the technology for more durable higher temperature chambers. These thrust chambers will allow higher performance to be obtained and will resolve compatibility problems of present regen-cooled chambers.

APPROACH: Regen-cooled chamber technology is currently the most limiting technology area in the Advanced Spacecraft Propulsion Design Studies. The high chamber pressures (1,500 psia) and the absence of film cooling (for higher performance) places difficult requirements on the regen-cooled thrust chamber. This program will investigate the use of high temperature capability materials and high temperature resistant coatings for regen-cooled thrust chambers. The program will include a study phase to evaluate potential materials and methods of fabrication. Samples will then be fabricated and tested to demonstrate their durability and compatibility with high temperature combustion products.

SCHEDULE: Start Work: Oct 84
Program Duration: 24 months

28. TITLE: LOW COST TITANIUM TANKS

OBJECTIVE: Demonstrate a lower cost method for fabrication of large titanium tankage for storable propellant satellites and advanced deployment systems.

PAYOFF: Low cost space systems.

APPROACH: Investigate low cost, simplified fabrication methods for large high quality propellant tanks for satellite application. Tankage will be fabricated and tested for typical satellite propulsion duty cycle requirements.

SCHEDULE: Start Work: Apr 85
Program Duration: 32 months

29. TITLE: STEP THRUST THROTTLING MODULAR ENGINE

OBJECTIVE: Integrate critical engine comonents into an engine assembly and demonstrate technology of a step thrust engine for modular space propulsion applications.

PAYOFF: This program will demonstrate and provide advanced, storable propellant rocket engine technology for deploying, transfering and maneuvering payloads over 10,000 lbm from the space shuttle orbit to geosynchronous altitudes. This technology will provide increased mission flexibility with a single propulsion system.

APPROACH: Results from an AFRPL in-house storable engine program and the Advanced Spacecraft Engine Components programs for high pressure storable propellants will be used to design, assemble and demonstrate the capability of a step thrust throttled engine system. This program will consist of five phases: I - Critical review of previous program results and engine system integration and cycle balance studies, II - Component and engine design and analysis, III - Component fabrication, IV - Component and subsystems tests, V - Integration and engine system demonstration. Injector and turbomachinery performance, thrust chamber heat transfer characteristics and high area ratio nozzle performance will be evaluated for selected mission duty cycles.

SCHEDULE: Start work: Jan 85
Program Duration: 60 months

30. TITLE: CRYOGENIC AUXILIARY CONTROL SYSTEM INTEGRATION STUDY

OBJECTIVE: Investigate the possibility of integrating the primary propulsion, the attitude control propulsion system (ACS) and the fuel cells for cryogenic deployment systems.

PAYOFF: Simplify and reduce the weight of cryogenic deployment systems for orbit transfer vehicles.

APPROACH: Studies and analysis shall be conducted to determine the feasibility of integrating the primary, the attitude control propulsion systems and fuel cells for orbit transfer vehicles. The studies shall include inputs from the Large Space Structure Cryogenic Deployment System Study program for the primary propulsion system. Possible areas of consideration for the ACS are ULP (ultra low pressure) engines, electric pump fed engines, and high pressure applications. The analysis shall define the most effective means (transfer time vs propellant requirement) for deploying various payloads to their operational orbits. Considerations for reducing cost and improving reliability shall also be included.

SCHEDULE: Start work: May85
Program Duration: 15 months

31. TITLE: CRYOGENIC PROPELLANT ABORT DUMP He/GAS GENERATOR STUDY

OBJECTIVE: Identify and demonstrate technology for the development of a helium/gas generator associated with Airborne Support Equipment(ASE) abort systems for future Air Force Large Space Structure (LSS) payloads carried in the Space Shuttle.

PAYOFF: A reduction of ASE weight for an Air Force LSS deployment vehicle could be realized. Such an ASE weight reduction would directly increase the deliverable GEO payload weight.

APPROACH: Utilizing results from the LSS Cryo Deployment System Study, Contract F04611-81-C-0048, conduct an analysis, design, and demonstration effort to define a He/gas generator required to handle anticipated AF LSS requirements.

SCHEDULE: Start work: Mar 85
Program Duration: 24 months

32. TITLE: LOW THRUST CRYOGENIC ENGINE TECHNOLOGY

OBJECTIVE: Develop and demonstrate the technology required to provide a long duration (approximately 10 hours), low thrust (500 lbf) pump-fed O_2/H_2 engine capability for Large Space Structure (LSS) deployment systems.

PAYOFF: The results of this program will provide the demonstrated capability of low thrust pump-fed engine technology for LSS deployment systems which will require long operating times for low thrust-to-weight transfer of LSs from the shuttle orbit to GEO.

APPROACH: Detailed studies and trade-off analyses will be conducted based upon the results of the LSS Cryogenic Deployment System Study, the Small Cryogenic Engine Boundary Layer Loss Investigation program (AFRPL's in-house program) and the Compact LO_2 Feed System Technology program to develop the overall design approach. Pump efficiency will be a major design parameter considered in the approach. Two pumps (one each OX and fuel) will be provided to a follow-on engine program. Design verification tests at the engine component level will be employed to afford iterative evaluation of design approaches to converge upon an "optirnum" point design. the design will be fabricated as a flight-type unit and tested with the flight-type pumps to anticipated mission duty cycles.

SCHEDULE: Start Work: Feb 85
Program Duration: 24 months

33. TITLE: FUEL VENTING MODELLING

OBJECTIVE: To develop a numerical model of the behavior of a jet of liquid injected into a vacuum.

PAYOFF: The ability to predict the behavior of liquid jets injected into a vaccum.

APPROACH: A numerical model shall be developed of the time dependent process by which a jet of liquid water or MMH, which is injected into a vacuum evaporates, shatters, freezes and possibly recondenses. The model shall describe the expansion cloud in terms of temporal distributors of particle, droplet and gas phase densities and velocities. The model shall be verified by comparison to the data from the Fuel Venting Radiation/Measurements program at AEDC.

SCHEDULE: Start Work: May 85
Program Duration: 29 months

34. TITLE: MANEUVERING PROPULSION SYSTEM STUDY

OBJECTIVE: Define the critical component technology requirements and develop conceptual designs of an advanced storable bipropellant propulsion system for satellite maneuvering propulsion.

PAYOFF: Provide the optimum propulsion system for satellite maneuvering propulsion. This study will identify the propulsion system which will give the near-term optimum delta V capability for the least weight in a reliable manner.

APPROACH: The requirement for improved satellite survivability is becoming increasingly apparent. Maneuveirng is an attractive near-term option but, because it results in significant additional satellite weight, it is very important to identify optimum maneuveirng system designs. This study and the follow-on system development and demonstration effort will give the Air Force the option to develop maneuvering satellite capability during the early 1990's. Trade off studies will be conducted to identify optimum propulsion system designs for maneuvering propulsion modules having minimum detrimental impact on the parent satellite capabilities. Both pump fed and pressure fed systems utilizing N_2O_4/MMH will be considered during the study. With a targeted near-term IOC, low development risk and maximum utilization of existing propulsion system components will be emphasized. The optimum propulsion system will be selected on the basis of reliabiity, performance, and satellite operational considerations. Both critical technology needs and system performance sensitivities will be identified during the study.

SCHEDULE: Start Work: Aug 85
Program Duration: 8 months

35. TITLE: PULSE GAS ELECTRIC THRUSTER VALVE DEVELOPMENT

OBJECTIVE: To develop a valve for pulsed gas electric thrusters

PAYOFF: The development of probably the most critical component of pulsed gas electric thrusters.

APPROACH: Pulsed gas electric thruster efficiency is critically dependent on the synchronism of the injected gas flow with the arc current discharge. The two must be precisely timed for maximum fuel utilization efficiency and thrust performance. In addition, the valve must be fast (microsecond rise time) and durable (capable of tens of millions of on/off cycles of millisecond duration).

SCHEDULE: Start work: Oct 84
Program duration: 24 months

36. TITLE: ELECTRIC PROPULSION MISSION REQUIREMENTS

OBJECTIVE: Conduct an assessment of electric propulsion needs for the 1990-2000 time period.

PAYOFF: Electric propulsion systems have the potential of increasing payload capability to GEO by a factor of 10 over chemical propulsion.

APPROACH: The contractor will maintain careful watch over DOD space mission planning activities with the intent of spotting trends or high interest in specific missions. The contractor will determine if these findings portend a change in electric propulsion performance and system requirements which could affect AFRPL electric propulsion programs.

SCHEDULE: Start Work: Oct 84
Program Duration: 24 months

37. TITLE: ADVANCED PULSED PLASMA THRUSTER CONCEPTS

OBJECTIVE: To advance the performance of the Teflon Pulsed Plasma Thruster (PPT).

PAYOFF: A simple electric propulsion system capable of meeting the auxiliary propulsion requirements of large space systems (LSS).

APPROACH: This program will consist primarily of theoretical studies followed by experimental verification of some of the major theoretical points on performance and operation. Ideas to be pursued include increasing total impulse capability through the use of liquid propellant or alternative fuel bar feed schemes, increasing specific impulse and/or efficiency through higher pressure discharges, current discharge wave shaping, etc. Recommendations for PPT designs which could significantly improve performance over the present millipound PPT design will be made. Significant improvement means on the order of a three fold increase in total impulse capability and a 50 percent increase in thrust efficiency.

SCHEDULE: Start Work: Oct 84
Program Duration: 12 months

38. TITLE: CRITICAL EVALUATION OF PROPELLANT INGREDIENT DATA

OBJECTIVE: Compile library of critically evaluated heat of formation data for propellant ingredients.

PAYOFF: Greater accuracy and uniformity within the industry for calculations of rocket performance.

APPROACH: Poll industry to find out the major fuels, oxidizers, binders, plasticizers, burn rate modifiers, and other special purpose additives that are in common use. Perform literature search for available calorimetric data and judge the literature sources for reliability. Compile a library of the heat of formation data available from all sources.

SCHEDULE: Start Work: Mar 85
Program Duration: 12 months

39. TITLE: DIFUNCTIONAL BINDER DEVELOPMENT

OBJECTIVE: Screen available polymers/bonding agents or develop new ones having potential to reduce cost or enhance the binder properties for solid propellants.

PAYOFF: To provide affordable propellants with improved properties with alonger shelf life.

APPROACH: There are new polymers (e.g., all cis polybutadiene, polyisoprene, saturated polyisoprene) availabe which have the potential of being very stable and producing good propellant properties. There are slso new ones that can be developed for specific propellant requirements. The polymer industry will be canvassed to see if any additional ones exist. These will be screened in small scale propellant mixes with current curatives, or develop new curatives, and with such techniques as epoxide or azide curing agents to determine the feasibility of developing a binder system which is well-behaved during and after cure.

SCHEDULE: Start Work: Apr 85
Program Duration: 42 months

40. TITLE: ANTIOXIDANT EFFECTS ON PROPELLANT PROPERTIES

OBJECTIVE: Determine antioxidant effects on the properties of HTPB propellants containing new metal ingredient additives.

PAYOFF: Achieve the stability of uncatalyzed propellant systems in HTPB propellants containing metal additives through effective antioxidants.

APPROACH: Several new metallized ingredients, i.e., ferric fluoride, are being included in HTPB propellants that contain "off-the-shelf" antioxidants. Many of these propellants are experiencing mechanical property degradation. Efficient antioxidants need to be found for use with the new metallized ingredients in order to achieve the stability of uncatalyzed HTPB propellant systems. This program will investigate the effects of antioxidants on several HTPB propellant systems containing metallized additives. Both "off-the-shelf" and new antioxidants shall be pursued. Many small scale propellants shall be studied to determine antioxidant effects on mechanical properties. At least two different HTPB propellant systems shall be scaled-up to the five gallon mix size. The mechanical properties of the scaled-up mixes wil be determined at several different temperatures. Appropriate aging studies shall be done, i.e., lined carton accelerated aging.

SCHEDULE: Start Work: Apr 85
Program Duration: 24 months

41. TITLE: VELOCITY COUPLING

OBJECTIVE: To develop and validate practical methods for predicting velocity coupling and its effect on motor stability.

PAYOFF: Enhanced ability to accurately predict the stability of solid rocket motors. Thereby reducing motor development problems and cost, while increaisng reliability.

APPROACH: The Velocity Coupled Microwave program will provide a means for measuring the transient burning rate of solid propellants, subject to acoustic velocity oscillations. This technique, together with other advanced diagnostic techniques shall be used to measure the fundamental flow and combustion parameters of interest. Both slab rocket motors and more benign rocket motor simulators shall be utilized. The effects of: shock-boundary layer interactions; surface roughness; acoustic boundary layer transition to turbulence; and particle induced turbulence suppression shall be determined. Existing analytical models for predicting: the effect of acoustic velocity oscillations and turbulence on the transient burning rate of solid propellants shall be reviewed and extended to allow prediction of the important experimentally observed phenomena.

SCHEDULE: Start Work: Mar 85
Program Duration: 44 months

42. TITLE: TEMPERATURE SENSITIVITY VERIFICATION

OBJECTIVE: To verify temperature sensitivity tailoring guidelines, as defined from the Temperature Sensitivity Technology Program in subscale motors.

PAYOFF: Reduced temperature sensitivity will provide increased performance equivalent to 3 - 7 seconds of specific impulse.

APPROACH: Tactical motors must operate effectively under a wide range of storage/launch temperature conditions. The variable thrust resulting from large temperature effects on burn rate and chamber pressure requires over design and/or off optimum to account for minimum thrust and maximum pressure (MEOP) requirements. Formulations identified in the Temperature Sensitivity Technology program will be evaluated, in nominal BATES motors, over a full range of temperature (-50° C to +75° C) and pressure (3.4 MPa to 27.6 MPa). The combustion response for these formulations will also be examined.

SCHEDULE: Start Work: May 85
Program Duration: 36 months

43. TITLE: PROPELLANT FLOW EFFECTS ON BALLISTICS

OBJECTIVE: To identify and control the effects of solid propellant rheology on propellant ballistic properties.

PAYOFF: Control of inconsistencies in propellant ballistics due to rheological effects will increase motor reliability.

APPROACH: Solid rocket motors, particularly large ones (i.e., strategic missile stages) are subject to burn rate inconsistencies, and possible failure due to effects which can be principally categorized as rheological. Propellant /motor ballistics will be correlated with processing variables such as shear stress viscosity, particle setting, pour flow lines, and propellant components.

SCHEDULE: Start Work: Dec 85
Program Duration: 34 months

44. TITLE: IMPROVED STANDARD LIQUID PERFORMANCE PREDICTION

OBJECTIVES: To verify accuracy of newly developed injector spray field and reactive stream models and update and integrate these into the Standard Distributed Energy Release (DER) porgram.

PAYOFF: Provide validated, advanced models for analytically characterizing injector spray and reactive stream models. These models, when incorporated in the Standard DER program should significantly reduce the time and cost required to accurately predict liquid rocket performance by obviating the need for extensive experimental liquid spray characterization eforets. More accurate performance predictions, reduce engine development risks, broader application and increased utility of computer programs.

APPROACH: Identify the best and most relevant data base for evaluating the spray field and reactive stream models. The predictions of these models will then be compared to the data and assessed. If required, model refinements will be implemented to improve the accuracy and/or generality of the models. The models will also be tailored, if needed, for ease of implementation into the Standard DER performance model.

SCHEDULE: Start Work: Oct 84
Program Duration: 54 months

45. TITLE: SPRAY FIELD AND REACTIVE STREAM MODELLING

OBJECTIVES: (1) Formulate theoretical models for liquid jet breakup, mixing and droplet formation. (2) Develop a model which accurately predicts reactive stream separation under various engine operating conditions.

PAYOFF: More accurate, non-empirical based spray field and reactive stream separation characterization. Enhances general applicabiity of analysis. Improves and facilitates performance and stability analyses. Reduced development risks. Reduces cut and try - saves time and money.

APPROACH: The program consists of two tasks:

TASK I - SPRAY FIELD MODELLING

Formulate from basic principles theoretical expressions which describe jet breakup, interaction, mixing, and recirculation. Droplet formation will be based on the shedding rate of liquid from the jets. Expressions will be developed for the various types of impinging jet pattersn of interest. Models will be verified with experimental data.

TASK II - REACTIVE STREAM MODELLING

Extend work on reactive stream separation (RSS) to develop an accurate model to predict the conditions under which RSS occurs. Both analytical and experimental tasks are to be conducted for different propellants, injection and engine operating conditions.

SCHEDULE: Start Work: Oct 84
Program Duration: 36 months

46. TITLE: DROPLET MECHANISMS IN OSCILLATING FLOW

OBJECTIVE: Investigate the combustion response of monopropellant droplets and sprays to imposed flow and pressure oscillations.

PAYOFF: Stable and reliable monopropellant thrusters

APPROACH: The understanding of the combustion of liquid droplets and sprays under oscillatory flow conditions is critical to minimizing presure oscillations in Air Force liquid rocket engines. Very few, if any, experimental studies of nonsteacy liquid droplet combustion have been conducted. Data is needed to further characterize droplet behavior in realistic combustion environments and to verify injector spray field and reactive stream models used in the Standard Distributed Energy Release Program. Conduct experimental and theoretical investigations of monopropellant droplet and spray combustion subject to imposed cross flow and pressure oscillations.

SCHEDULE: Start Work: Oct 84
Program Duration: 30 months

47. TITLE: NON-LINEAR CONTITUTIVE THEORY TRANSITION

OBJECTIVE: Develop an engineering version of the advanced propellant constitutive law for cost-effective motor structural analysis.

PAYOFF: Reliable calculations of safety margins and service life without costly test programs to calibrate analysis results.

APPROACH: Based on the results of the Propellant Nonlinear Constitutive Theory Extension Program, The High Elongation Propellant Technology Program, and the Propellant Finite Deformation Program, produce a version of the best candidate propellant constitutive law which is adaptable to rocket motor analysis procedures. Effort will concentrate on techniques to minimize computational problems without loss of accuracy in stress-strain response. Some verification work with analog motors will be included.

SCHEDULE: Start Work: Jul 85
Program Duration: 33 months

48. TITLE: CHEMICAL MIGRATION REACTION MODELS

OBJECTIVE: Produce a methodology for the solution of migration reaction problems in solid rocket motors.

PAYOFF: Elimination of failures at rocket motor bonded interfaces.

APPROACH: Determine the diffusivities and solubilities of various solid propelalnt mobile species in solid propelalnt rocket motor components. Determine the effect of migrated propellant ingredients on the aging characteristics of propellant grain, liner, insulator, barrier, case, and the bonded interfaces. Determine migration effects on both structural and ballistic properties. Obtain a three-dimensional computer solution for migration throughout the propellant grain, liner, barrier, insulator, case, and especially the bond regions. Recommend standard package involving experimental and mathematical modeling techniques for predicting effects of migration on chemical and physical properties of solid rocket motors.

SCHEDULE: Start Work: Mar 85
Program Duration: 30 months

49. TITLE: REMOTE TRANSFER OF HAZARDOUS MATERIALS

OBJECTIVE: Develop and study the techniques and procedures for the safe, remote transfer of hazardous materials from accidently damaged or unsafe containers located in the Space Shuttle payload bay.

PAYOFF: Demonstrated remote transfer system, techniques and procedures for the safe, remote transfer of hazardous materials from accidentally damaged or otherwise unsafe containers in order to reduce risk to emergency response teams, reduce or eliminate environmental contamination, and provide for the removal of endangered material which could increase the severity of an accident. The techniques and procedures developed will be of benefit to all branches of the Department of Defense, Federal, State and Local emergency response teams and civilian industry.

APPROACH: A contractor will be selected to study the feasibility of and identify methods of remote hazardous materials transfer from accident sites. The contractor will design and build a prototype transfer system which will be demonstrated in-house at the AFRPL.

SCHEDULE: Start Work: Jul 85
Program Duration: 16 months

50. TITLE: CONTAMINATION DESIGN CRITERIA

OBJECTIVE: To establish standard contamination abatement criteria for spacecraft design.

PAYOFF: Minimize the effects of contamination on satellite lifetime and spacecraft mission effectiveness.

APPROACH: The contractor will devise a set of standard criteria for the minimization of satellite contamination. These criteria will cover the design of satellites and their handling up until launch. The criteria will provide satellite contractors with specific guidelines for determining allowable contamination levels, selecting and preparing propulsion systems and materials, performing contamination analyses, designing and testing satellite systems, monitoring contamination levels, and handling/storing satellites before launch. The final result will be a contamination design criteria handbook for satellite and subsystem designers, and SPO's.

SCHEDULE: Start Work: Oct 84
Program Duration: 36 months

51. TITLE: ADVANCED CONTAM MODEL IMPROVEMENT

OBJECTIVE: Provide a CONTAM model capable of predicting plume contamination from solid, and liquid thrusters and end-of-life surface degradation.

PAYOFF Ensure that launch payloads, satellite life-time, and spacecraft mission effectiveness are not degraded by exhaust plume contamination.

APPROACH: The CONTAM IV model will expand the capabilities of the CONTAM III model. CONTAM IV will emphasize the modeling of solid rocket motors, whereas CONTAM III was designed for liquid engines. CONTAM IV will include improvements for handling small droplet and particle flow, and other items to be identified during use of CONTAM III. CONTAM IV will also offer the opportunity to improve the analytical methods used in various portions of the program. Perhaps most important, we will emphasize making the CONTAM program easier to use. The CONTAM IV model will also contain a much-improved surface effects model. This effort will be multi-source.

SCHEDULE: Start Work: Oct 84
Program Duration: 36 months

52. TITLE: HAVE BUSK A CONCEPT SPACE EXPERIMENT DESIGN

Program details are classified.

53. TITLE: OPTICAL TEST BED

OBJECTIVE: To develop a structure control laboratory experiment suitable for evaluating and demonstrating active control of structure to optical tolerances.

PAYOFF: Demonstration of critical control theory, sensing and actuation.

APPROACH: This is a contract program to develop a small scale laboratory optical structure for the AFRPL In-House Control Demonstration/Experiment program. Use of commercially available optics (Questar telescope, for example) with deliberately flimsy support structure and an IR source and detector is the anticipated approach.

SCHEDULE: Start Work: Dec 85
Program Duration: 21 months

54. TITLE: SATELLITE ACOUSTIC SENSOR STUDY

OBJECTIVE: Investigate the use of acoustic sensors to monitor the health of bearings, moving parts or mechanical systems on board satellites.

PAYOFF: Provide more information about the condition of various satellite components to avoid or correct failures.

APPROACH: A study shall be conducted to identify the moving parts and mechanical systems present on a typical satellite. Experiments shall then be conducted to identify the acoustic signature emitted by those components before and during failure. Components to be studied include moveable antenna bearings, bearings of despun platforms, gyroscopes or other inertial navigation equipment, or moveable thermal control panels.

SCHEDULE: Start Work: Apr 85
Program Duration: 18 months

55. TITLE: LIQUID DROPLET RADIATOR FEASIBILITY DEMONSTRATION

OBJECTIVE: Demonstrate the feasibility of the Liquid Droplet Radiator Concept through actual subscale testing.

PAYOFF: The rejection of heat in space is a critical aspect of virtually all proposed space-borne installations from solar power satellites to nuclear powered satellites. The problem is very critical for nuclear satellites which are being proposed by the Air Force. Current designs for radiators are bulky and heavy. The radiator mass currently comprises a large fraction of the total system mass, and consequently forms a critical design problem for many space systems. Moreover, cooling problems currently exist in the storage of cryogenic propellants and there is, consequently, a need for an active refrigeration system. A lighter and more efficient radiator would have a significant impact on a wide variety of Air Force Space/Propulsion programs.

APPROACH: Data obtained from prevous and on-going work at NASA and by the Air Force will be used to establish the best test system for establishing concept feasibility. Test hardware will be fabricated and testing will be conducted.

SCHEDULE: Start Work: Apr 85
Program Duration: 24 months

56. TITLE: DIRECT CONTACT HEAT EXHANGER FOR SPACE

OBJECTIVE: To determine the feasibility and regions of applicability of Direct Contact Heat Exchangers for use on Air Force Space Systems.

PAYOFF: The thermal management of future space power systems will require the use of heat exhangers to bring heat into and out of the working fluid. Conventional tube-in-shell and corrugated plate heat exchangers are heavy and unreliable due to the large surface area required for the heat exchange. Thermal fatigue of the metal surfaces cause frequent leakage of working fluid due to cracks. A reliable and lightweight heat exchanger will have a significant impact on future space systems. Furthermore, it appeears that an advanced direct contact heat exchanger would complement the advanced radiator concepts being studied by the Air Force Rocket Propulsion Laboratory.

APPROACH: Conduct analytical studies to determine performance characteristics and identify the most promising design configurations. Conduct experimental research to verify analytical results. In particular, experiments will be conducted to establish the heat transfer characteristics between the two fluids making contact.

SCHEDULE: Start Work: Dec 84
Program Duration: 12 months

57. TITLE: HAVE BUSK C ENHANCEMENT PROGRAM

Program details are classified.

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