U S A F A
Space
Systems
Research
Center

NASA Technology Roadmaps: Propulsion and Power Workshop

Aeronautics and Space Engineering Board

National Research Council

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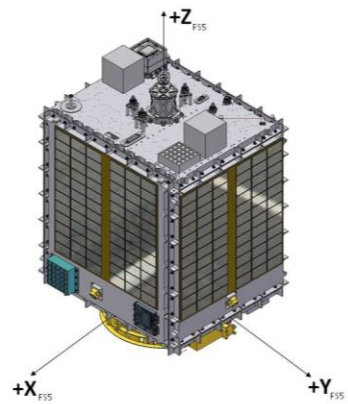
TA01 Panel Objectives
Earth to LEO

USAFA Space Systems Research Center

- Perspectives on launch propulsion technology investment priorities
- Choice of investment technologies to:
  - Increase capabilities for NASA missions
  - Lower mission costs
  - 20 year timeline for benefits
- Identify single most important launch propulsion technology



Unfettered input

USAFA SSRC Perspectives

- Combined FalconSAT & FalconLAUNCH course
  - One organization: DFAS/SSRC aerospace company
  - Optimized faculty and cadet efforts by prioritizing SSRC projects
  - Cadets organized into teams within particular disciplines
    - Mechanical
    - Systems Engineering
    - Management
    - Operations
    - Payloads
    - Avionics

- Programs
  - FalconSAT-3: on orbit operations (ESPA)
  - FalconSAT-5: launch and early orbit operations (ESPA)
  - FalconSAT-6: PDR (ESPA)
  - FalconSAT-7: conceptual design (cubesat)
  - FalconLAUNCH-T1: successful avionics & recovery system

Develop useful skills for aerospace careers

Program Goals

- Let Cadets “Learn Space by Doing Space”
  - Real-world, Hands-on Experience
  - “Cradle-to-Grave” of Space Missions
    - Mission Design
    - Payload and Subsystem Development
    - Assembly, Integration & Testing
    - Launch & On-orbit Operations
    - Program Management

- Support Dept of Defense space S&T objectives
  - Be a *Real* US Air Force Program
  - Do *Real* DoD Science (not just an academic program)
  - Bring in *Real* outside money to support program
- Training a Cadre of Space Professionals

Low cost, frequent access to space essential

FalconSAT Test Methodology

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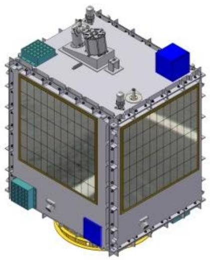
FEM → CLA1 → CLA2 → FEM2 → CLA3 …

LVI docs ..

PM



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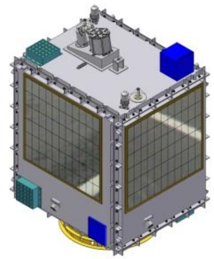

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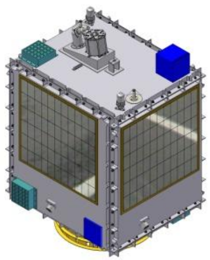

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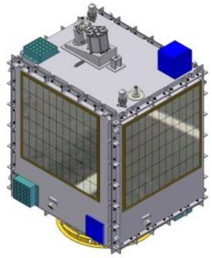

- Physical design and configuration

- Dynamic testing
  - qualify design
  - qualify assembly procedures
  - establish component qual random vibration levels

- Dynamic/thermal testing
  - qualify components without heritage
- Hardware testing
  - Verify functionality requirements
  - Verify performance

- Dynamic testing
  - demonstrate workmanship of flight interfaces
  - verify flight assembly
- T-Vac
  - accept components
  - functionality testing

Validate compliance with launch vehicle

Example Launch

- Launch date: 19 November 2010
- Launch vehicle: Minotaur IV
- Launch site: Kodiak Launch Complex
- Final orbit: 650 km, 72 deg inclination

Integration support

Legitimate LV costs / time still large; not just $/kg

More Investment Criteria

- What is government role?
  - Only spend where industry can not / could not / should not
  - Basic research at NASA (and universities)
  - Unique government requirements
- STEM
  - Worse every year → affect TA01 investment strategy?
- Learn from previous government programs
  - Development of commercial nuclear energy industry
  - Armor/AntiArmor program (DoD/DOE/industry large & small)
- Role of IRAD
  - Where does NASA investment leverage and promote?

How many technology investment decisions would be moot if there was healthy commercial (and military) market?

Solid Rocket Propulsion Systems

- Status
  - Long history of success
  - Known reliabilities and costs
  - Close to nominal propulsion limits
- What would make a difference in a launch system?
  - More energetic material → marginal improvement
  - Hybrids, variable stage → useful improvements
  - Software modeling → always good, but ... Must be open if NASA funded
- NASA role
  - Basic research support for advanced propellants

Majority of investments would be made in response to market drivers

Liquid Rocket Propulsion Systems

- Status
  - Known reliabilities and costs → more complex systems operation and materials problems
  - More room for system improvement
- What would make a difference in a launch system?
  - New fuels (difficult engineering) → useful improvement
  - Hybrids, variable stage → useful improvements
  - Software modeling → always good, but ... Must be open if NASA funded
- NASA role
  - Basic research support for advanced materials, combustion chemistry, and complex systems

Majority of investments would be made in response to market drivers

Air-Breathing Propulsion Systems

- Status
  - Unknown reliabilities and costs → more complex systems operation and materials problems
  - Much room for system improvement → to what end?
- What would make a difference in a launch system?
  - Very clear application / mission statement that enables ABLPS to promise *significant system improvement*
  - Does NASA define problem and solution, or just problem?
- NASA role
  - Opportunity for basic science and applied engineering investment tied to specific goals

Most likely technical area to provide reusable, lower cost to orbit, integration(?) significant improvements in 20 years

Ancillary Propulsion Systems

- Status
  - Capabilities exist in all subsystems today
  - Normal evolution of engineering skills, and cross fertilization from other fields, should continue
- What would make a difference in a launch system?
  - All identified opportunities are useful → $ by whom?
  - What technologies are unique to NASA problem?
- NASA role
  - Opportunity for limited basic science and applied engineering investment tied to specific goals

Great set of engineering problems to work on: should be result of industry providing best system solution to opportunity

Unconventional / Other Propulsion Systems

- Status
  - Engineers always need dreams → promote STEM?!
  - Base nuclear technologies still 50 years old
  - Potential for significant materials and system design improvements in fission systems
  - Fusion still 20 (30?) years away
- What would make a difference in a launch system?
  - Reality → No reason to invest in any engineering (TA01)
- NASA role
  - Opportunity for sponsorship of dreamers → important

Nothing on this list likely to influence next 20 years of launch;
But *<u>most promising areas</u>* for in-space propulsion and power

Investment Recommendations

- How
  - Basic research critical for STEM & workforce
  - Strong encouragement of industry / university collaboration where possible
  - Spend some investment dollars in buying advanced performance systems from industry and let competition drive engineering decisions
  - Leverage unique NASA knowledge and facilities
- What would make a difference in a launch system?
  - ABLPS have largest near-term performance promise
  - Focus on integrated systems → drive subsystem performance

NASA secondary mission should always be inspiration

Investment Recommendations

- Air-Breathing Launch Propulsion Systems
  - Need to down select quickly and smartly to meet 20 year goal
  - Pick two competing technology paths for system
    - Down select at demonstration level
  - Sprinkle basic research support for alternatives
- My (pragmatically arbitray) order of priority
  - Ramjet/Scramjet engines
    - Multi-year investment in demonstration system (compete)
    - Technology decisions made by providers
    - Protect IP while collaborating with NASA

I have no stock in any related business ….