



14th Annual FAA Commercial Space Transportation Conference

NOFBX[®] Monopropulsion Overview

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- **Who We Are:**
 - Firestar Technologies and ISP Systems Overview
- **What we are Commercializing**
 - NOFBX® past development overview
 - NOFBX® current development overview
 - NOFBX® future development overview
- **Flight Opportunities and Ground Support Equipment Preparation**
 - International Space Station Flight Experiment
- **Wrap-up**

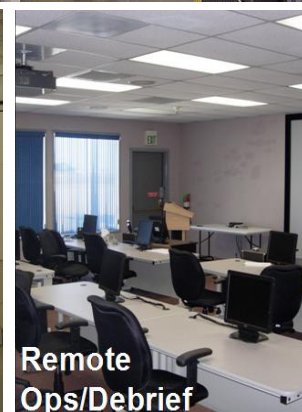


Who We Are (2/2)

Innovative Space Propulsion Systems

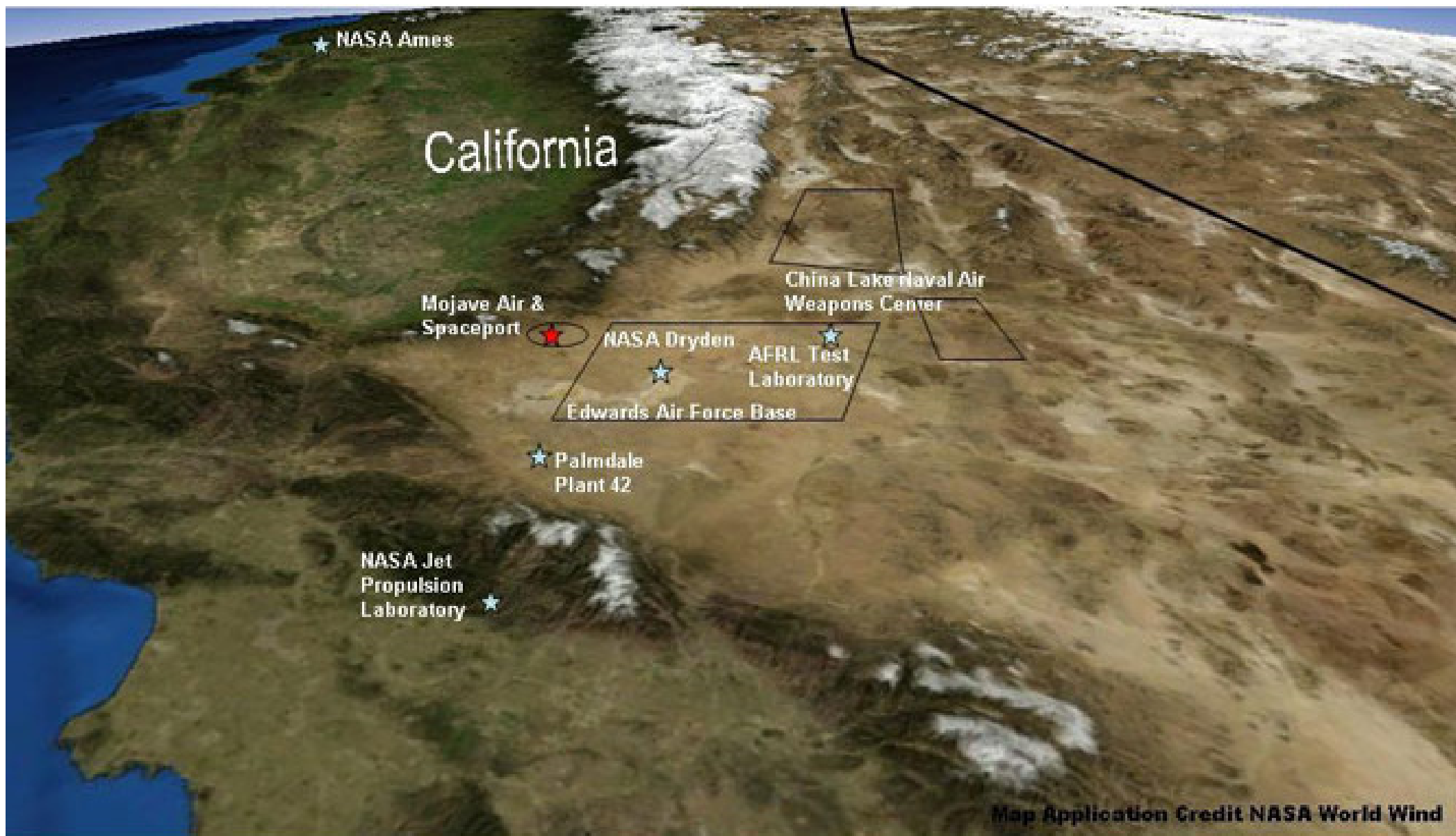
NOFBX® Monopropulsion Overview

- Texas company with HQ within blocks of NASA JSC
- Following successful DoD SBIR supplier chain business model, ISPS is a manufacturing incubator for NOFBX® propulsion technology
- Enterprise of 6 aerospace R&D, business, and manufacturing entities with vested interest for all parties
- Combines resources and skills of all companies critical to commercializing NOFBX® products



Mojave Area Aerospace Activities

NOFBX® Monopropulsion Overview



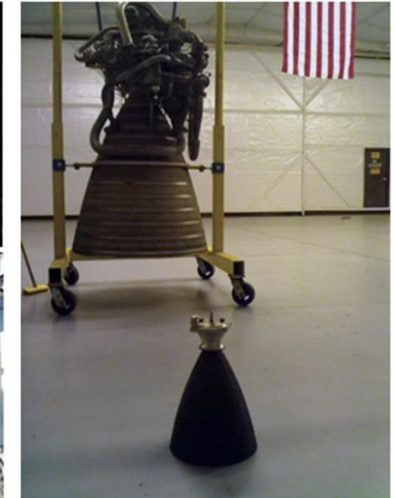
What are We Selling (1/3)

NOFBX® Technology Overview

NOFBX® Monopropulsion Overview

- **Revolutionary Advanced Chemical Propulsion Technology**
 - Non-Toxic, “Green”, monopropellant replacement to all In-Space Chemical Propulsion Systems (hydrazine, LOX/Fuels) with Isp performance comparable to bipropellants
 - Very simple self-pressurizing feedsystem with engines capable of operating from any fluid phase (think propane bottle and thruster replacing stove)
 - Deep throttling, very light weight engines that can readily replace engines in a over a magnitude of thrust class (0.05 – 5 lbf), (1-100 lbf)
- **NOFBX® technologies radically reduces cost of In-space integrated propulsion systems, ground handling costs and liability, and overall aerospace and flight system costs**

Exhibit 2-1 Risk of Toxic Hypergolic Propellant Exposure





What We Are Selling (2/2)

NOFBX[®] Technology Comparison to Existing Systems

NOFBX[®] Monopropulsion Overview

Characteristic	Solids	Bi-prop Liquids	Bi-prop Hypergol	Monoprop Hypergols	Hybrid	NOFBX [®] Monoprop
Storable	Yes	No	Yes	Yes	Yes	Yes
Throttleable	No	Yes	Yes	Yes	Yes	Yes
Non-Toxic	No	Yes	No	No	Yes	Yes
Environmentally friendly	No	Yes	No	No	Yes	Yes
Fast start-up	Yes	No	Yes	Yes	Yes	Yes
Restartable	No	Yes	Yes	Yes	Yes	Yes
High Specific Impulse	No	Yes	Yes	No	Marginal	Yes
Low acoustics	No	No	No	No	Yes	Yes
Low part-count	Yes	No	No	Yes	Yes	Yes
Common Abort/On-Orbit	No	Yes	Yes	Yes	No	Yes



NOFBX[®] Monoprop System Applications

Commercial Crew and Commercial Launch

NOFBX[®] Monopropulsion Overview

- ***Offers global replacement for NTO/MMH and monopropellant Hydrazine***
 - ***Number one recommendation from 2010 CRAFT study (Joint NASA/Air Force/FAA Commercial Space Task Force) for commercial space development is provide an affordable, replaceable, non-toxic solution to hydrazine that a large number of commercial developers can ultimately handle***
- **Addresses fundamental issue with “Hydrazine Bomb” problem in commercial launch vehicles**
 - A hydrazine fueled re-entry payload (~1000 kg typical) looks like a “chemical warhead” with lower IDLH exposure limits (~40 ppm) than “Agent Orange”
 - Crew or Earth return capsule applications that have reentry insulation to prevent reentry capsule break-up are of particular concern especially with launch range envelopes that ultimately cannot avoid large populated areas (e.g. Europe on ISS inclinations)
 - Launch Abort Systems must not only prevent rupture of hydrazine tanks during hard impact to keep crew alive, but also minimize threat to surrounding population. Can potentially utilize common NOFBX[®] monopropulsion system for either crew abort or on-orbit ops
 - Financially insuring commercial launches to non-toxic chemical energy sources is straightforward (e.g. distance/energy calcs) compared to hydrazine contamination plumes (where random surface winds need to be taken into consideration)



NOFBX[®] Monoprop System Applications

In-Space Propulsion Advantages

NOFBX[®] Monopropulsion Overview

- **Non-toxic and high Isp (> 320s).**
 - Rapid development of new high performance commercial and government spacecraft systems without constraints of toxic handling issues
 - Constituents can be procured locally in DOT certified containers/processes and mixed on-site to support advanced spacecraft development and testing
- **Extreme Temperature Tolerant for robust, passive storage even in extreme space environments**
 - < 80°C freezing point
 - 390°C - > 700°C thermal ignition limit (good engine coolant)
- **Self-Pressurizing**
 - For everything but very high propellant consumption rate missions, doesn't necessarily require separate pressurant system or propellant management device
- **Propellant Transfer**
 - Single fluid
 - Heating source tank by < 5° C is sufficient to generate 10's of psia pressure gradient to drive and condense monopropellant into receiving tank (No pumps).



NOFBX[®] Monoprop System Applications

Commercial Crew and ISS Operations

NOFBX[®] Monopropulsion Overview

- **Proximity Operations and Autonomous Rendezvous and Docking benefit dramatically from NOFBX[®] attributes**
 - **Deep throttling**
 - **Allows for fine control to better meet docking / robotic capture conditions**
 - **Minimizes plume disturbances and heating**
 - **Non-toxic: No contamination hazard to ISS (or other destinations)**
 - **H₂O is only NOFBX[®] exhaust plume condensable (and will sublime away)**
 - **Other gases include > 50% N₂, ~20% CO₂ and <15% of CO + H₂**
 - **Ideal for repeated visit locations**
 - **Ideal for “inspection” activities**
- **Alternative re-boost capability**
 - **Opportunity to provide non-toxic, high performance U.S. ISS boost option to current Russian Zvezda NTO/MMH system**

NOFBX[®] Monopropulsion Systems Development

NASA (JPL) Mars Technology Program Development

NOFBX[®] Monopropulsion Overview

–77°C NOFBX[®]
Monoprop



Goals and Objectives:

- Produce a >300s Isp, high energy density (~10x of SOA batteries) monopropellant propulsion system that is non-toxic, self-pressurizing, deep-space-storable, low temp tolerant and ultimately lower cost than NTO/MMH

Achievements (2004-2007 for <\$650K):

- Developed NOFBX[®] monopropellants (patents pending)
- Demonstrated NOFBX[®] monoprop impact /electric shock insensitivity and extreme temp (<-80°C to >700°C) tolerance
- Developed two-phase NOFBX[®] fluid regulation systems
- Invented /Demonstrated redundant NOFBX[®] anti-flashback and feedsystem detonation arrestors (patents pending)
- Demonstrated >300s vacuum equivalent Isp in NOFBX[®] monopropellant brassboard thrusters (patents pending)



NOFBX[®] Monopropellant 5.5m Impact and Hi Temp Ignition Limit Testing



Line Detonation Qualification Testing of NOFBX[®] anti-flashback feedsystem



First >300s NOFBX[®] Thruster w/ two-phase fluid-handling and anti-flashback feedsystem

NOFBX[®] Monopropulsion Ascent Engines

NASA Altair Lunar Lander Studies

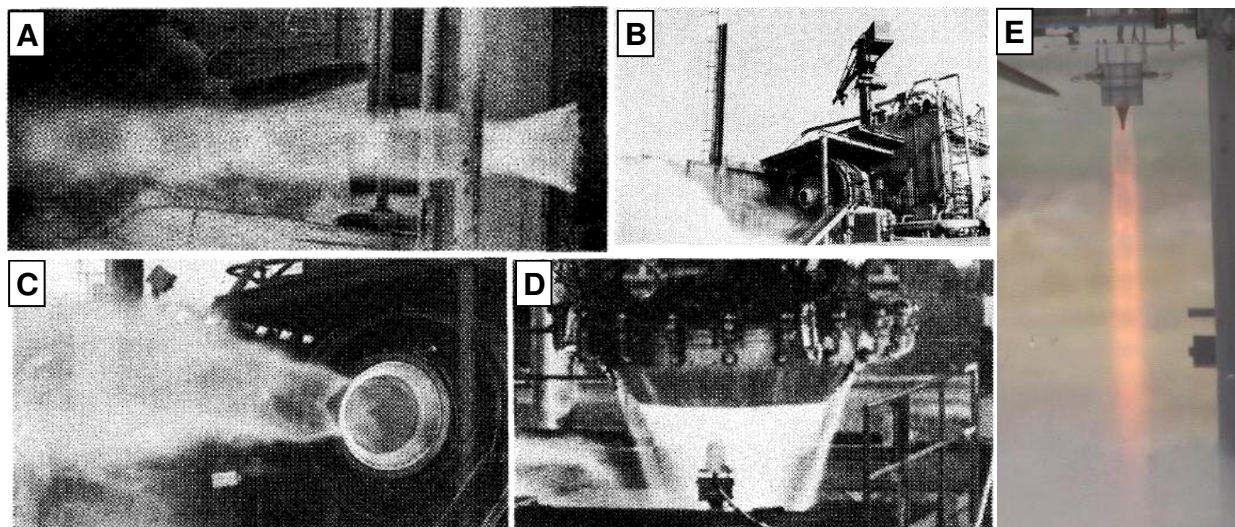
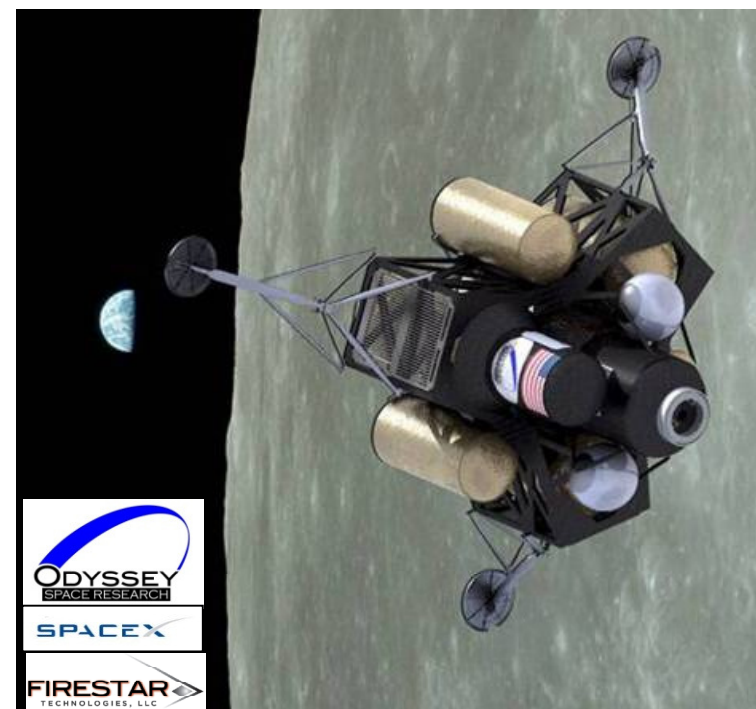
NOFBX[®] Monopropulsion Overview

Goals and Objectives:

- Investigate NOFBX[®] monopropulsion system options for Altair Lunar Lander and Constellation program

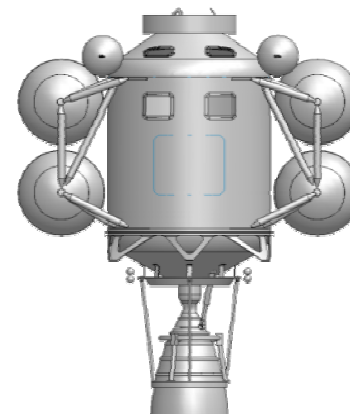
Achievements (2008 for <\$50K):

- Developed NOFBX[®] monopropellant compact engine/nozzle designs for Altair Lunar Lander Ascent Vehicle
 - Addressed fundamental Fire-in-the-Hole ascent engine risk for Altair lander with clean separation plane
 - Developed overall system reliability model for vision engine (Mungas et . al. 2008)
- Developed preliminary requirements for Multi-purpose, On-Orbit engine for Altair and Constellation Program

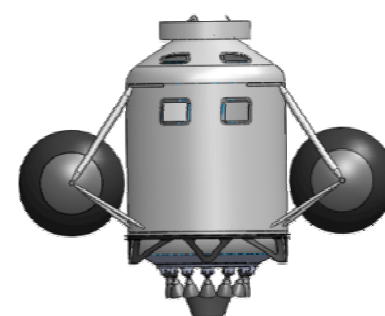


Truncated Aerospike Hot-fire Tests since 1960's

NTO/MMH Lunar Ascent Vehicle Baseline



Odyssey/Space-X /Firestar option



NASA Altair Lunar Lander Vehicle Configuration Studies

NOFBX[®] Monopropulsion Systems Development

NASA SBIR Phase I/II Funded 1-100 lbf Thruster Development

NOFBX[®] Monopropulsion Overview

Goals and Objectives:

- Produce a versatile, highly throttle-able (1-100 lbf), high Thrust-to-Weight (T/W), robust, NOFBX[®] workhorse in-space thruster that can burn liquid, two-phase, or gas phase NOFBX[®] monoprop, and operate in a pulsed mode or continuously in fully insulated conditions (e.g. in reentry insulation)

Achievements (2008-2010 @ \$700K):

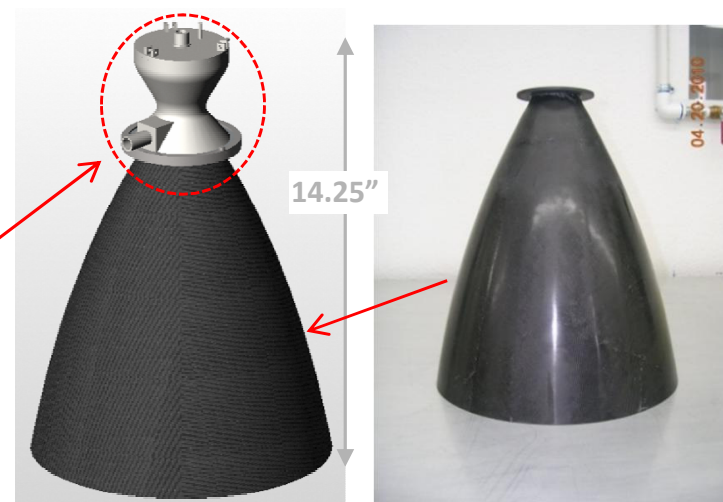
- Invented micro-fluidic porous media coolant jackets and injectorhead that can operate over multiple fluid phases (patents pending)
- Developed and demonstrated the first (non-hydrogen) gas-cooled rocket engine in history
- Improved T/W by 200% over current NTO/MMH SOA 100 lbf, ~325s Isp
- Assembled MIL-STD test equipment for future joint FAA MIL-STD /STANAG testing of NOFBX[®] monopropellants for civil space service



First gas-cooled NOFBX[®] thruster in history on permanent display in NASA IPP office, Washington, D.C.



NOFBX[®] Monopropellant 25 lbf vacuum equivalent atmospheric hot-fire testing

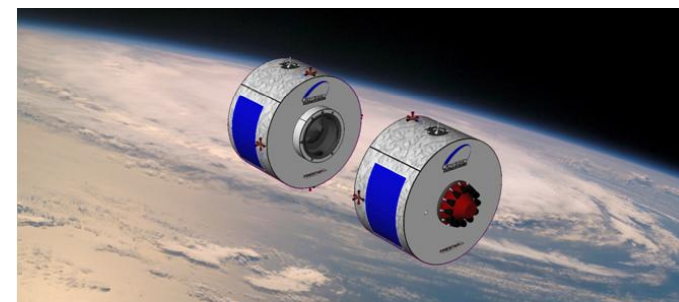
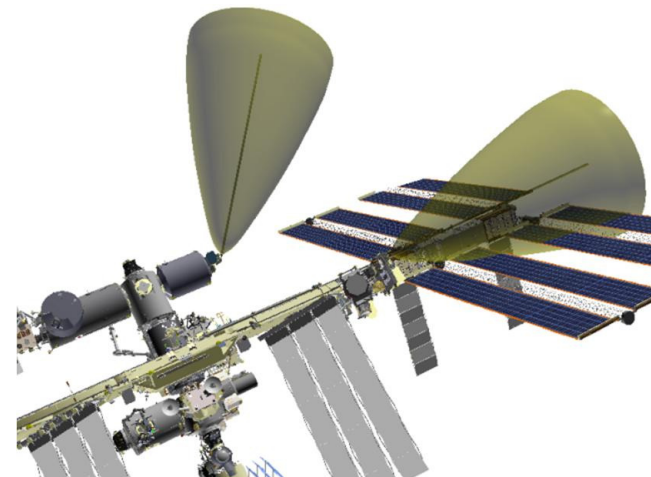


NOFBX[®] 1-100 lbf thruster and 200:1 carbon-carbon vacuum nozzle

ISS National Lab BAA for Flight Demonstration Opportunity (1/2)

NOFBX® Monopropulsion Overview

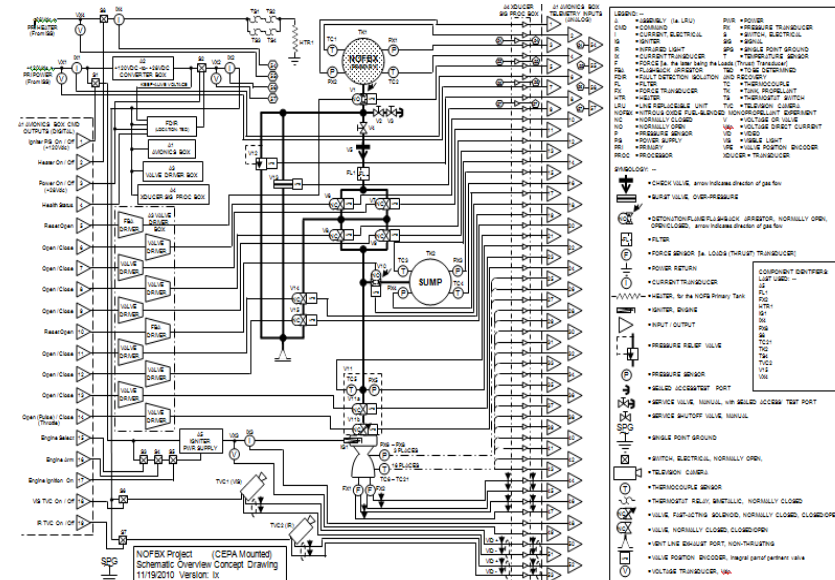
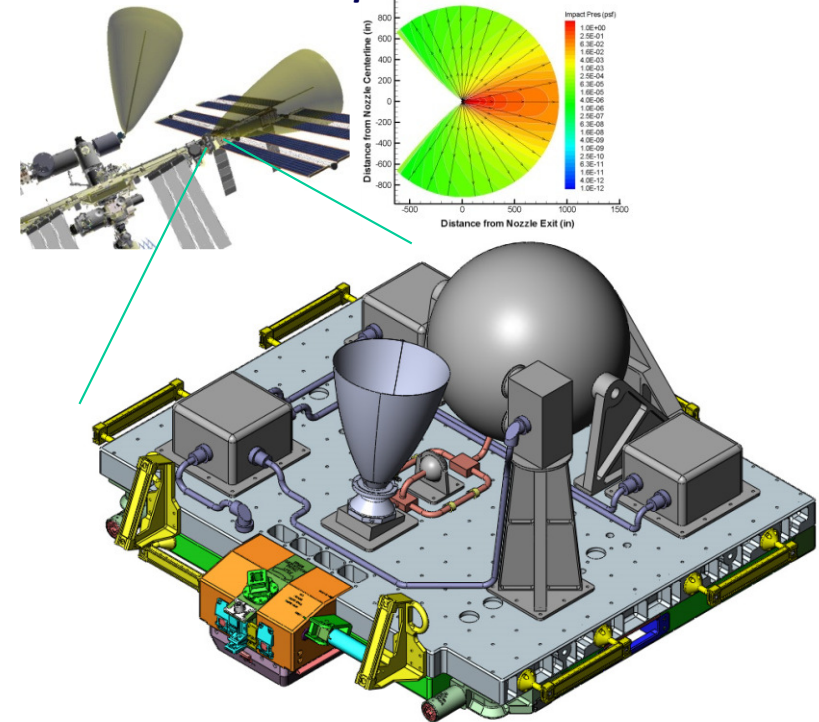
- **Critical risk reduction activity**
 - Community won't baseline without "flight time"
- Precursor to many "ground-breaking" follow-on demo options and future manufacturing activities:
 - U.S. Boost option for ISS (non-toxic)
 - AR&D demo of ISS / commercial rendezvous technologies, including "tug" operations
 - Highly throttle-able, non-toxic, low contamination plume
 - Autonomous Rendezvous and Docking technologies
 - On-orbit monopropellant transfer for single-fluid space-storable commercial and government fuel depots
 - **Commercial Launch Abort System (CCDev opportunity)**
 - Non-toxic, common propulsion system for launch abort AND on-orbit maneuvering
 - **Feedforward to other NASA programs**
 - Single-Stage-to-Orbit Sample Return launch systems
 - Low temp tolerant propulsion for deep space
 - Non-toxic, Cubesat/Nanosat propulsion for rapid R&D



ISS National Lab BAA for Flight Demonstration Opportunity (2/2)

NOFBX® Monopropulsion Overview

- Awarded through NASA BAA NNH10CAO001K: *Enabling Support Equipment and Services for International Space Station as a National Lab*
- ISS FRAM payload (arm deployed to Truss)
- Purpose of Experiment
 - Demonstrate all operating modes of NOFBX® on-orbit commercial engine including all primary elements of NOFBX® propulsion subsystem
 - Engine Thrust chamber
 - Carbon-Carbon vacuum nozzle extension
 - Engine Rad-hard, miniature Ignition System
 - Main Engine Throttling Valve and anti-flashback systems
 - Go through ISS Safety Review Process for achieving “man-rating” equivalent
 - Requires manifested ISS payload
- Development team includes Boeing, Moog, JASC, ... and FAA funding for oversight testing
 - Endorsements from 13 major domestic and international aerospace companies



NOFBX[®] Monopropulsion Ascent Systems

SBIR Phase I/II PAV/MAV Engine Development

NOFBX[®] Monopropulsion Overview

Goals and Objectives:

- Conduct system architecture studies on Planetary Ascent Vehicle engines (i.e. MAV) for SMD applications. Develop very low profile, low mass NOFBX[®] nozzle designs that can be thrust vector controlled for ascent engines

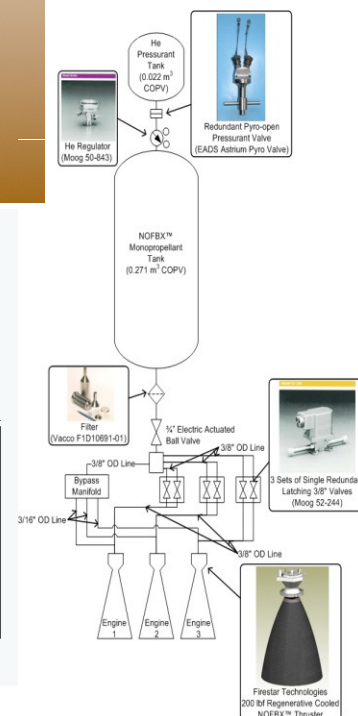
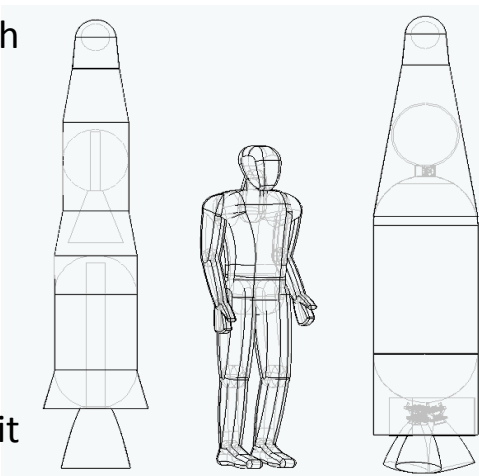
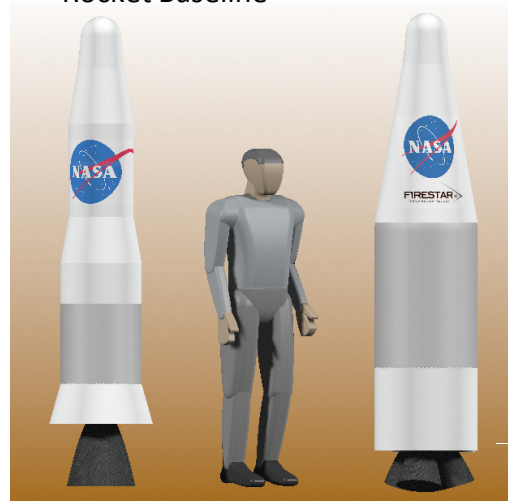
Achievements to date (2010 for <\$100K):

- Reviewed requirements for MSR MAV vehicle
- Developed NOFBX[®] monopropellant Single-Stage-to-Orbit (SSTO) MAV monopropulsion concept
 - Low temp tolerant monoprop provides long surface life
 - No staging potentially can eliminate requirements for full vehicle flight tests (no critical events during ascent)
 - 3x NOFBX[®] 200 lbf engines (100 lbf engines requal'd to 300 psia) with differential thrust reduces nozzle length and removes requirement for low temp mechanical gimbal
 - Highly throtttable/ Restartable engines for optimal, low drag trajectory, circularization burn and precision orbit placement
 - Non-toxic, low contamination plume. Low cost development/test
 - Simple helium pressurized monopropellant tank. EOL helium supports up to 50 m/s ΔV (e.g. rendezvous ops)
 - Large MAV on-orbit volume for supporting extended mission on-orbit (e.g. solar powered beacon) and break-the-chain operations
 - Feedforward – Readily reconfigurable for alternative Sample Return missions – Asteroid, Titan, planetary body, etc. PAV's
- Phase II award starting Feb. 2011 and work incorporated into 2 of 3 NASA awardees to Primes for Phase I MAV vehicle studies**

Design-for-Reliability 250 kg vehicle MAV Options

Current 2-Stage Solid Rocket Baseline

NOFBX[®] Single-Stage-to-Orbit



Clustered NOFBX[®] SSTO/Rendezvous propulsion system under SBIR contract for a Mars Ascent Vehicle Sample Return mission application

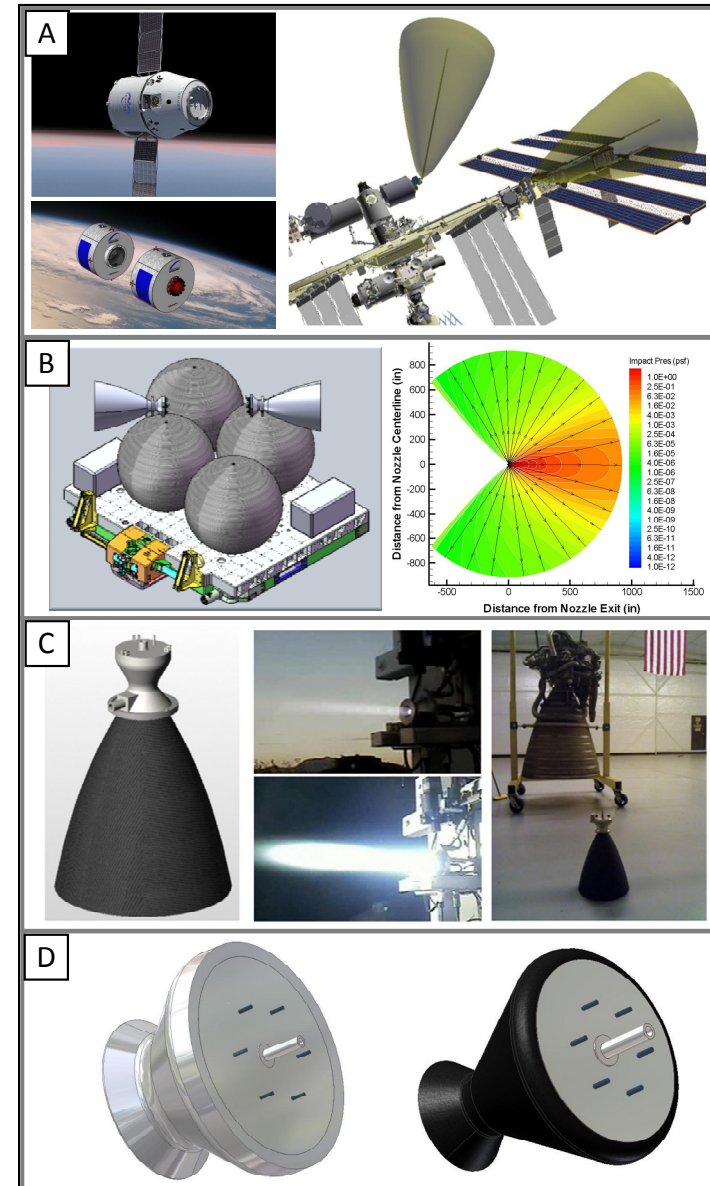
- Under FAA sponsorship of independent witness (Aerospace Corp), we are conducting MIL-STD2105C NOFBX[®] storage system tests
 - Completed MIL-STD2105C impact testing and qualified our NOFBX26, NOFBX29, and NOFBX37 blends .
 - Have completed designs and fabrication of Slow cook-off ground support equipment (90% complete) and test articles (85% complete). Tests scheduled to be initiated Feb. 2011
 - Have completed designs for Fast cook-off tests. Ground support equipment is ~50% complete. Tests scheduled to be initiated in March 2011



- **Completing Ground Test Facilities (e.g. Vacuum Chamber) for In-Space Testing**
- **Acquired Facilities for larger engine testing**
 - MAV vehicle development and hotfire test with Garvey Space Corporation under awarded NASA Phase II SBIR (vertical test stand)
 - Potential CCDev-2 development for crew escape engines (horizontal test stand)



- CCDev-2 awards in ~Mar 2011
- Purpose:
 - Provide non-toxic, in-space propulsion alternative to COTS vehicle developers
 - Provide significant savings in payload mass by removing separate launch abort system
 - Develop additional NOFBX® hardware for test on the ISS flight experiment
 - Working with 4 CCDev vehicle teams to develop requirements for a retrofit upgrade NOFBX® non-toxic, commercial propulsion system
 - Develop series of scaled prototype 10,000 lbf class engine for candidate crew escape/abort engine and evaluate reliability and ignition characteristics of a high thrust NOFBX® engine
 - Designed to burn unused orbit propellant load in an emergency scenario





NOFBX® Commercial and International Business Development

NOFBX® Monopropulsion Overview

- **Cleared to license for foreign manufacturing through Department of State-cleared published foreign patent applications**
- **For U.S. manufacturing and international market penetration, ISPS is pursuing Commodity Jurisdiction with Department of State and Commerce Department**
 - Commercial First Use Clause
 - NATO III ITAR guidelines as precedence for non-ITAR rating for ISPS NOFBX® In-space systems in U.S.
 - U.S. competition in export market is currently challenging (see Rockefeller et. al. 2009 Congressional Report, Office of Science and Technology Policy and M. Gold 2009, Thomas Jefferson, We Have A Problem")
 - Evaluating Technical Assistance Agreements and Manufacturing Licensing Agreement Options for overseas partners in manufacturing if manufacturing in U.S. for export is not allowed. Precedent exists.

- **Overview of NOFBX® non-toxic, high Isp, deeply throttle-able systems**
- **Described near-term commercial applications**
 - Multi-purpose, on-orbit propulsion system for ACS and orbit maneuvering, rendezvous/docking
 - ISS Awarded Flight Opportunity
 - Working down launch stack for NASA SMD small launch systems and future commercial kick stage motors
 - MAV SBIR awarded opportunity
 - Future opportunities for commercial crew escape systems
- **Described Facilities for in-space and larger engine testing**
- **International Business Planning**
- **Questions?**