NL1200

NanoLaunch1200

National Aeronautics and Space Administration

NanoLaunch 1200 to ADAS Enabling Affordable, Dedicated Access to Space through Aggressive Technology Maturation

Jonathan E. Jones, Timothy P. Kibbey, C. Brent Cobb, and Lawanna L. Harris

2014 Space Propulsion Conference, Cologne, Germany

Agenda

- MSFC and NanoLaunch organization
- Near Term Schedule
- The Goal: Affordable, Dedicated Access to Space
- Baseline Vehicle Concept of Operation
- "Heilmeier's Catechism" for NanoLaunch
- Concluding discussions

Propulsion Systems Department (ER01)

Manager – Thomas (Tom) J. Williams
Deputy Manager – Mary Beth Koelbl
Chief of Operations - Richard T. Stroud
Strategic Planning & Business Dev. – Thomas (Tom) M. Brown
SLS Discipline Lead Engineer – Michael (Mike) R. Ise
Technical Assistant – James L. Cannon
Technical Assistant – Thomas P. (Pat) Lampton

Resource Management Office (ER02)

Resource Management & Integration
Lead - Dawn M. Ray
Program Analysis Management Team
Team Lead – Terry D. Ware

Propulsion Systems Design & Integration Division (ER20)

Division Chief – Pat McRight
Tech Assist – Harold P. Gerrish
Lead Systems Engineer (Engines) – Philip A. Benefield

Engine Systems Branch (ER21)
Branch Chief – Mark N. Rogers
Deputy – Joseph (Joe) C. Leahy

Main Propulsion Systems Branch (ER22)
Branch Chief - Kathy L. Henkel

Spacecraft & Auxiliary Propulsion systems Branch (ER23)
Branch Chief – Charles (Chuck) Pierce
Deputy – Alicia A. Turpin

Propulsion Research & Technology Branch (ER24)
Branch Chief – James (Jim) J. Martin

Propulsion Component Design & Development Division (ER30)

Division Chief – Roger K. Baird

Turbomachinery Design & Dev Branch (ER31)
Branch Chief – Randall J. Thornton

Combustion Devices Design & Dev Branch (ER32)
Branch Chief – Gregg Jones

Valves, Actuators, & Ducts Design & Dev Branch (ER33)
Branch Chief – William (Kevin) Ward
Asst Manager – James (Jim) A. Richard

Propulsion Detailed Design Branch (ER34)
Branch Chief – David M. Whitten

Thrust Vector Control Systems Integration & Components Branch (ER35)
Branch Chief – Lisa B. Bates

Propulsion Structural, Thermal, & Fluid Analysis Division (ER40)

Division Chief – Stanley (Stan) W. Tieman
Tech Assist – Neill C. Murphy

Structural & Dynamics Analysis Branch (ER41)
Branch Chief – Patrick (Pat) R. Rogers
Deputy – Gregory (Greg) P. Frady

Fluid Dynamics Branch (ER42)
Branch Chief – Lisa W. Griffin
Asst Manager – Tom E. Nesman

Thermal & Combustion Analysis Branch (ER43)
Branch Chief – Melissa K. VanDyke

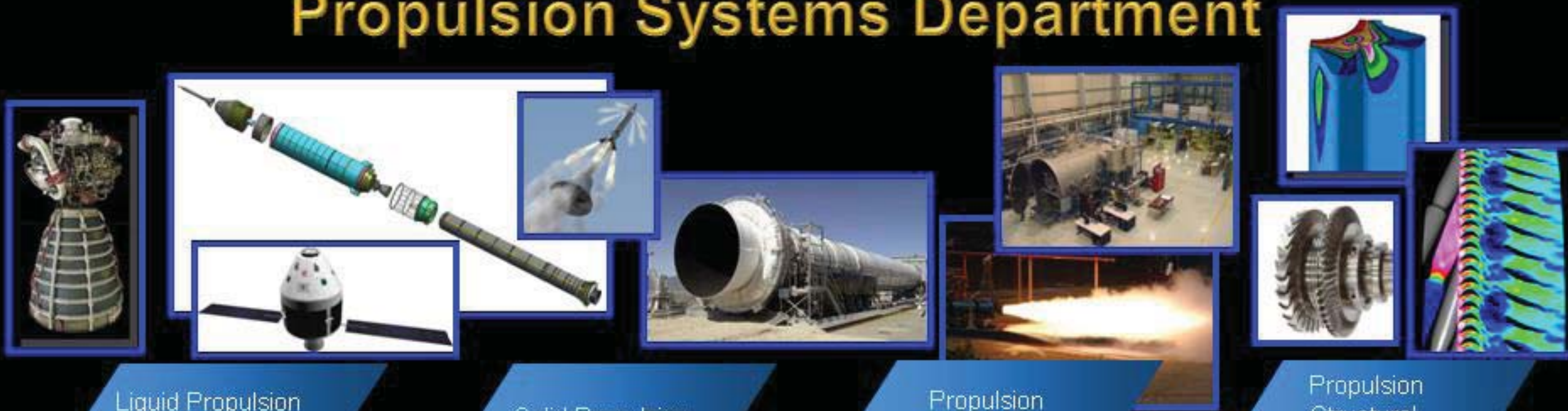
Solid Propulsion Systems Division (ER50)

Division Chief – Mark A. Cooper
Lead Systems Engineer (Boosters) – Edwin (Hank) Miller
Tech Assist – Jonathan E. Jones
Tech Assist – Timothy (Tim) W. Lawrence

Solid Launch Systems & Analysis Branch (ER51)
Branch Chief – Robert (Bobby) H. Taylor

Solid Separation & Maneuvering Systems Branch (ER52)
Branch Chief – Philip M. Franklin

Propulsion Systems Department



Liquid Propulsion Systems Design & Integration

- Liquid Engine Systems Design
- Engine Systems Analysis & Health Management
- Main Propulsion Systems Design & Analysis
- Spacecraft Propulsion System, Design, Analysis, & Testing
- Divert and Attitude Control Systems Technologies
- Design, Analysis, and Testing for Long Term Propellant Storage
- Advanced Propulsion & Power Research & Development including: High Power Electric Propulsion, Nuclear Thermal Propulsion, Space Nuclear Power Systems, and Nuclear Surface Power Systems.

Solid Propulsion Systems

- Solid Boost Propulsion Systems Integration
- Solid Motor Design and Analysis
- Separation & Maneuvering Solid Propulsion Systems Design and Development
  - Booster Separation Motor
  - Booster Deceleration Motor & 1st Stage Tumbling Motor
  - Ullage Settling Motor
- Launch Abort Motors
- System Ballistic Analysis
- Motor Component Design and Life Extension Expertise
  - Nozzle, Case, Propellant, Insulation, and Liner

Propulsion Component Design & Development

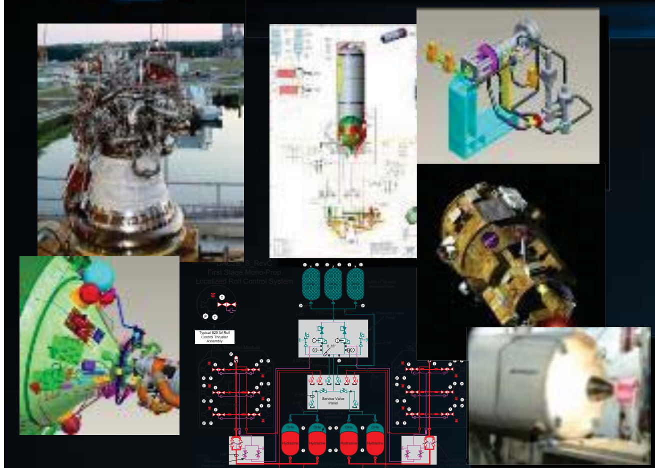
- Turbomachinery Design, Analysis and Advanced Development
- Combustion Devices Design, Analysis and Advanced Development
  - Injectors, Thrust Chambers, Nozzles, Preburners, Gas Generators, and Ignition Systems
- Valves, Actuators, & Ducts Design, Analysis, Test, and Advanced Development
- Detail Component and System Design
- Thrust Vector Control Systems Design and Development

Propulsion Structural, Thermal, & Fluid Analysis

- Strength & Life Assessment
- Dynamic Loads & Data Analysis
- Flow Testing & Analysis (Steady& Unsteady)
- CFD of Turbomachinery (Pumps and Turbines)
- Water Flow & Air Flow Testing of Components
- Unsteady Fluid Dynamics Data Analysis, Acoustic Analysis & Combustion Instability Analysis
- Thermal Analysis & Design for Liquids and Solids
- CFD of Combusting Flows - Liquid Systems & Solid Motors

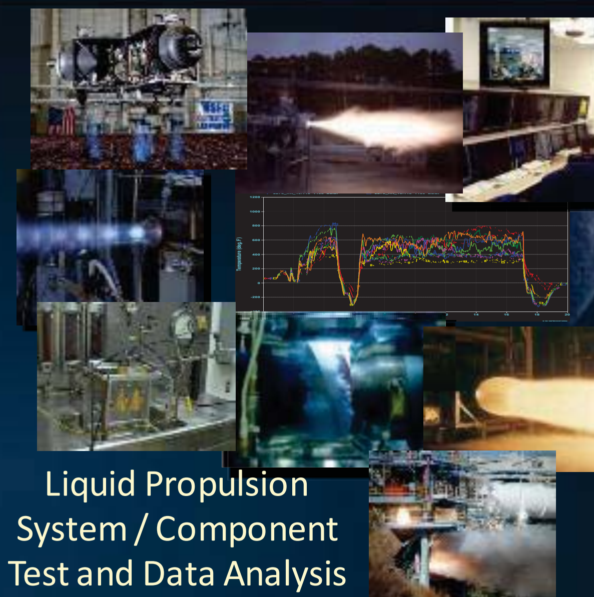
Liquid Propulsion Systems Design, Development, Analysis, Test and Anomaly Resolution

Propulsion Systems Department



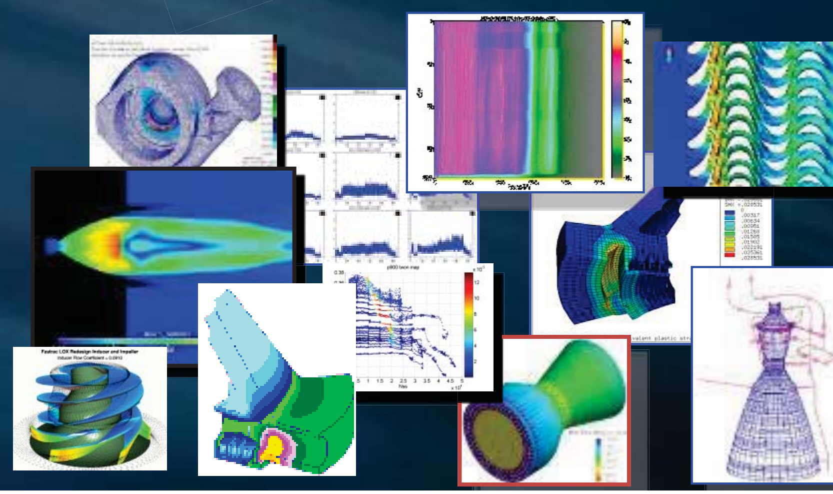
Engine, Main Propulsion System and Spacecraft Propulsion Systems Design

Turbomachinery, Combustion Devices, Lines, Valves, Actuators, & Detail Design



Liquid Propulsion System / Component Test and Data Analysis

Anomaly Resolution: Test and Life Issues

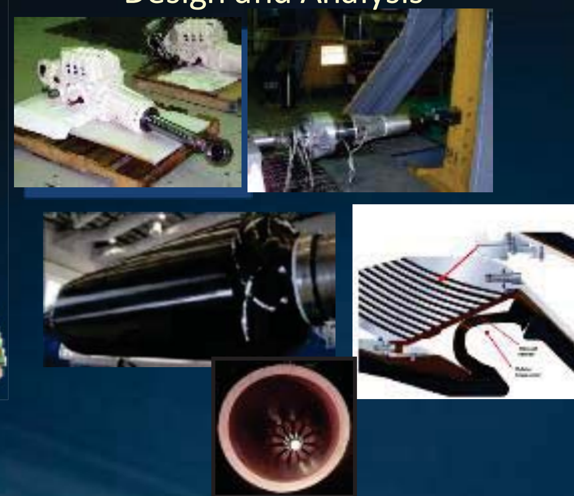


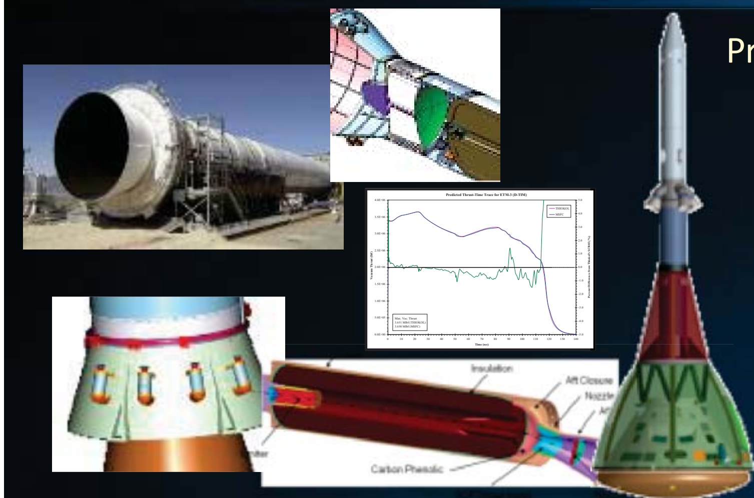
Liquid Propulsion Stress, Life Assessment, Loads and Dynamics, Thermal, Acoustics, and CFD Analysis

Solid Propulsion Systems Design, Development, Analysis, Test and Anomaly Resolution

Propulsion Systems Department

Propellant, Liner, Case, Nozzle and TVC Design and Analysis

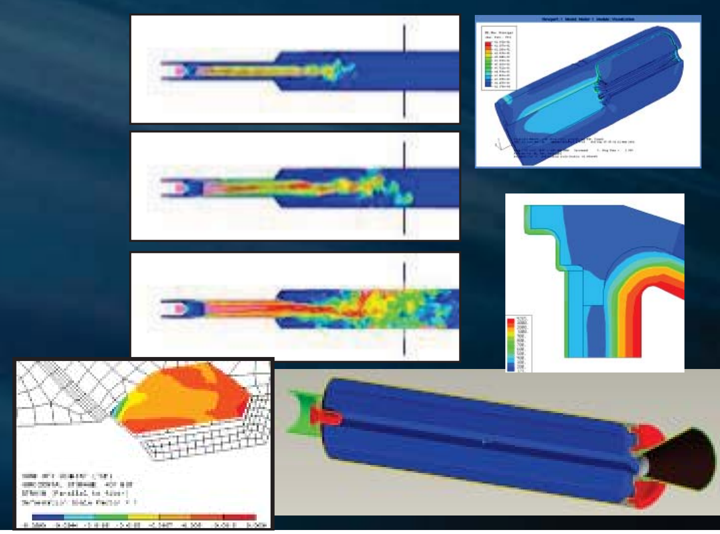




Booster Solid Systems, Solid Separation and Maneuvering System Design

Solid Propulsion System and Component Test and Data Analysis

Anomaly Resolution: Test and Life Issues



Solid Propulsion Stress, Life Assessment, Loads and Dynamics, Thermal, Acoustics, and CFD Analysis

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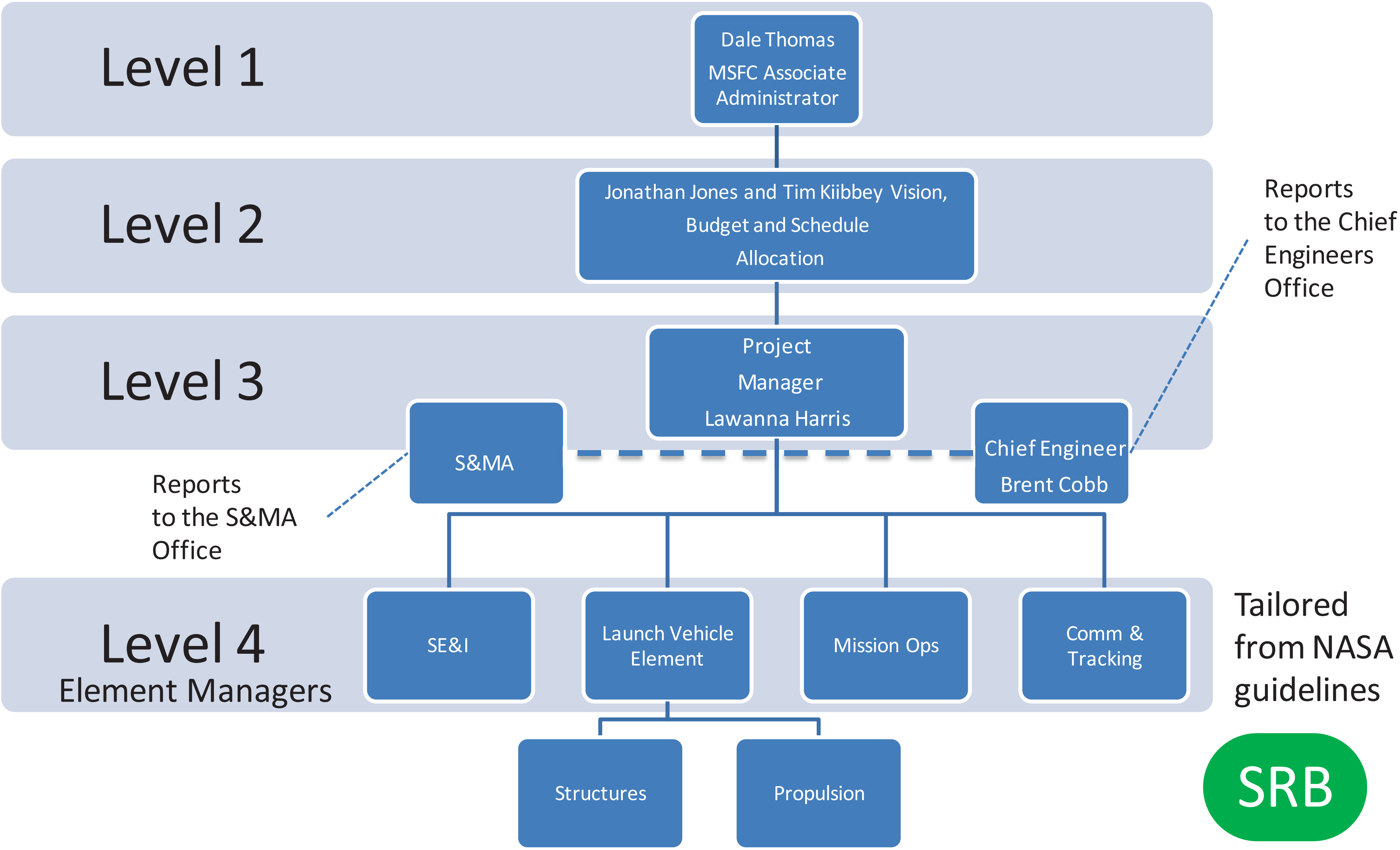
NanoLaunch 1200 Organization Structure

National Aeronautics and Space Administration



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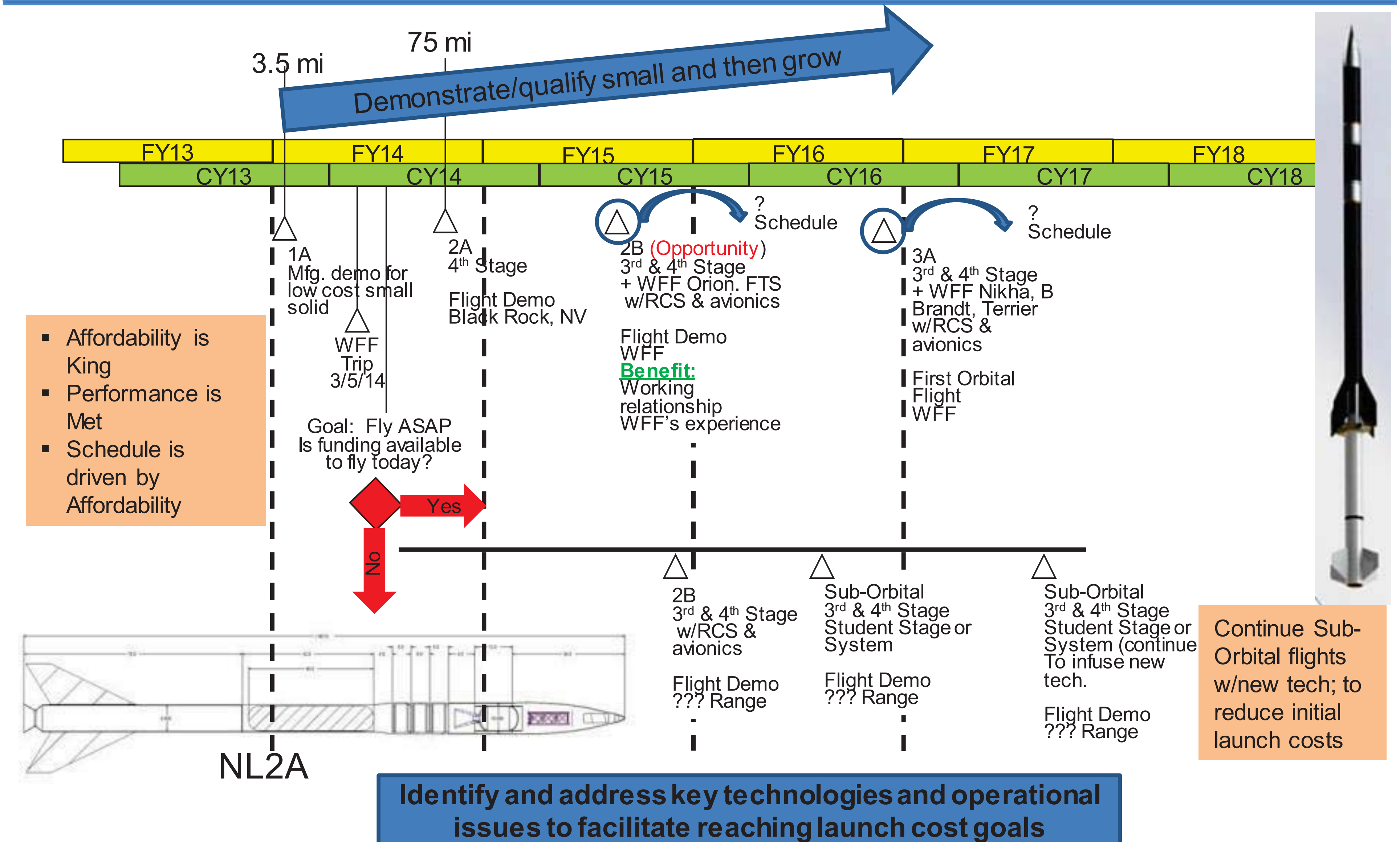
FY15 and FY16 Schedule

National Aeronautics and Space Administration



ADAS

A Path to Affordable, Dedicated Access to Space

Standardize "Plug-n-Play" Interfaces

Baseline Vehicle

PSRM-30

Cartridge loaded solid with integrated flight termination system

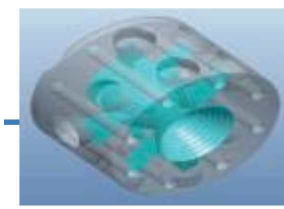
PSRM-120 and Nihka

Advanced "printed" liquid rocket engine, 2 stages upgraded to 1

Black Brant

Additively manufactured hybrid rocket motor, university coopetition

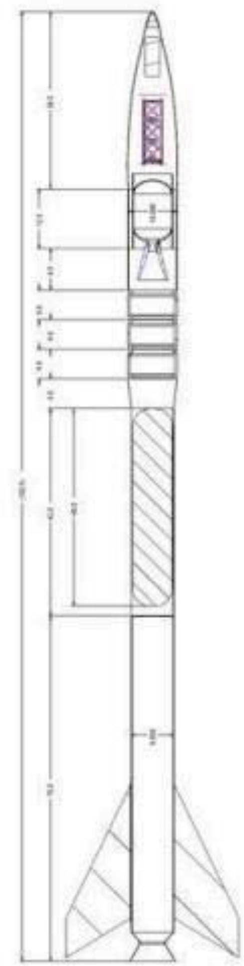
Terrier



SBIR/STTR development with integrated thrust vector control

Heritage FTS and Avionics

CNAT, MSFC, KSC avionics solution with autonomous FTS



ADAS

A flexible architecture allows multiple concepts and operational approaches to reduce costs.

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Concept of Operations

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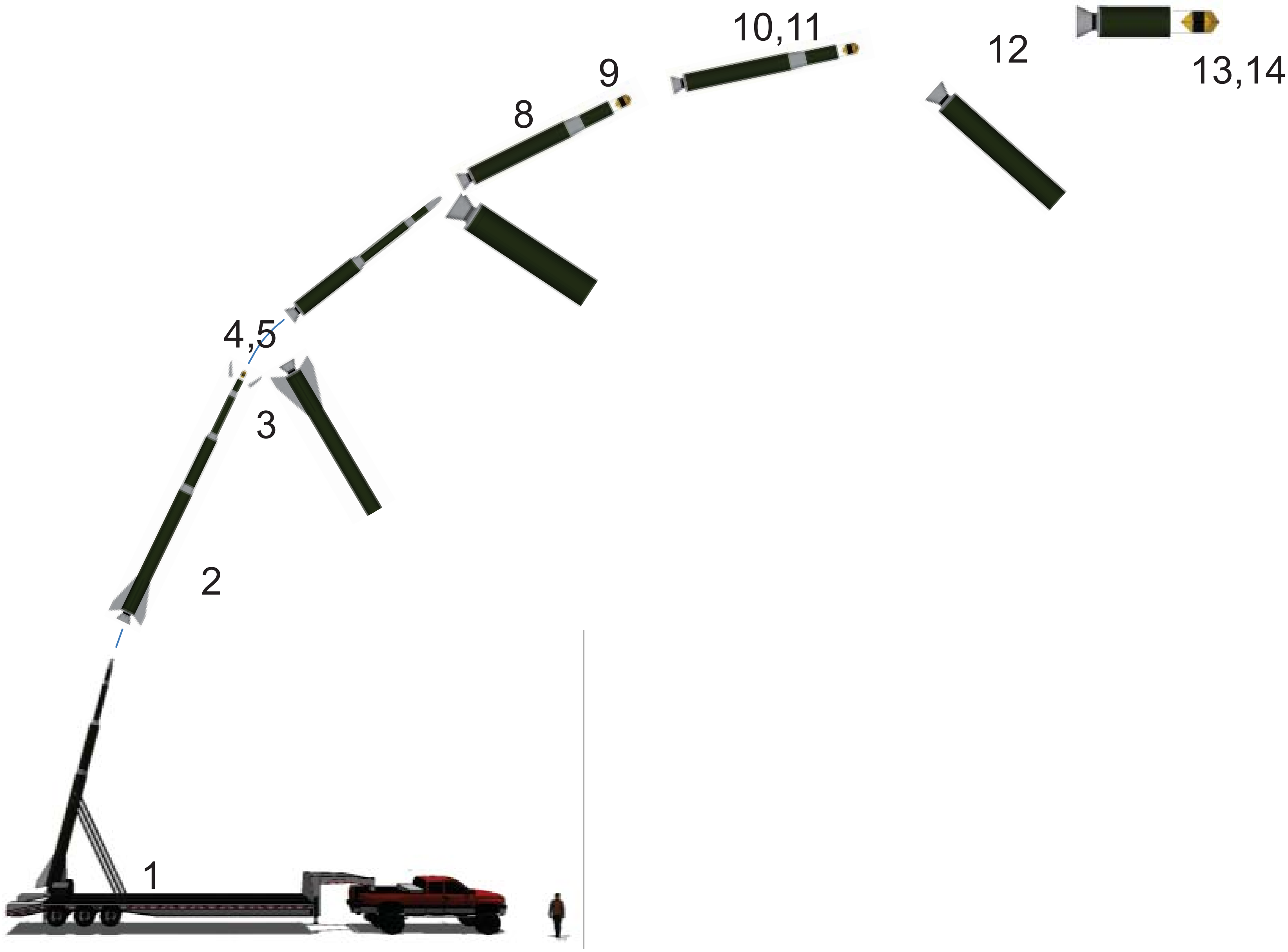


Objectives

- What are you trying to do?
  - Provide an affordable, dedicated small launch vehicle:
    - Mature innovative, high payoff technologies
    - Provide access to space for nano (1-10kg) payloads
- What is the problem?
  - No launch vehicle provides rides for experimental propulsive technologies
  - No dedicated, affordable vehicle to launch cubesats
  - Launch costs are prohibitive for maturing technologies from TRL3 to TRL6 (The TRL "valley of death")
    - For example, Pegasus is $30 - $50M
    - High risk (TRL3) technologies are often cut from the manifest as secondary payloads ($250 - $300K).
- Why is it hard?
  - Traditional aerospace industry and launch facilities have an enormous fixed cost
    - Sustaining flight rates high enough to lower launch costs have not been realized
    - Fixed costs can dominate the price of a small launch vehicle
  - Qualification requires flight environments
  - All integration and approvals required for large vehicles apply to small vehicles

Determine the payload size and reliability target that minimize the cost of a single successful launch

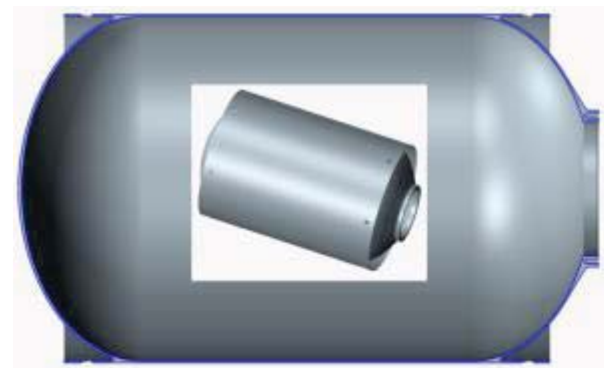
Current Status

- How is it done today and what are the limits of current practice?
  - The cost of current launch vehicles requires stringent risk management
    - Prohibits market growth
    - New technologies are tested in a laboratory environment and then set on a shelf
  - Cubesats fly as secondary payloads
    - High risk, high pay-off technologies have difficulty obtaining buy-in
  - Dichotomy between experimental aircraft and experimental rockets

Great Ideas…Zero Payoff

Approach

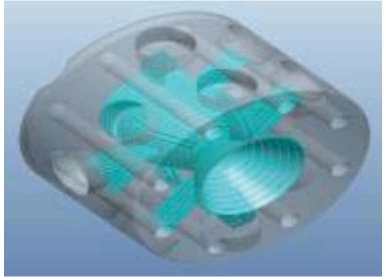
- What's new in your approach and why do you think it will be successful?
  - Reduce the cost of vehicle components
    - Use manufacturing techniques and components outside of traditional aerospace industry base
      - Additive manufacturing
      - COTS avionics packages
      - Smaller propellant vendors
    - Minimize component hand-offs
      - Small multi-disciplinary teams
      - Streamlined processes
  - Provide low-cost relevant flight environments
    - Utilize incremental launch vehicle approach--technology maturation with each flight
    - Leverage high-power amateur rocket community to mature candidate technologies

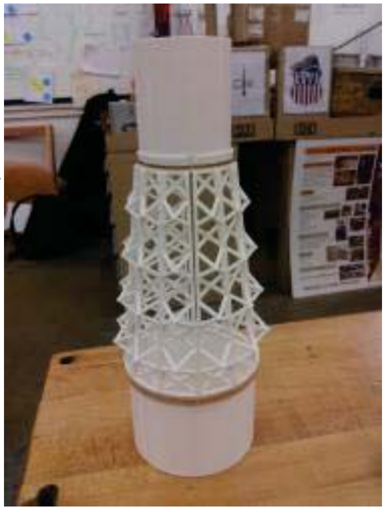


Engage companies and industries that support themselves while meeting our needs

Approach cont.

- What's new in your approach and why do you think it will be successful?
  - Reduce the assembly and integration complexity
    - Standardization of interfaces (plug-n-play)
    - Simplify processes (limit need for pyrotechnics or special equipment)
  - Partnering with academia and industry on cutting-edge technology.
    - Tapping NSTRF Fellows to mature cost-saving technologies
    - Utilizing Senior Design Projects
    - Teaming with small business and amateur rocket community
  - Right-sizing management approach
    - Model Based Systems Engineering (MBSE)
    - Agile Earned Value Management





Make it convenient for others to interact, collaborate, and participate

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University Coopetition

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Benefits

- If you're successful, what difference will it make? What impact will success have? How will it be measured?
  - New technologies can be matured from TRL 3-6 within the scope and budget of a Phase II SBIR
  - Dedicated rides for cubesats…the backlog for cubesats is eliminated
  - Clear path for the demonstration and fielding of novel manufacturing techniques
  - Allows aerospace avionics to keep pace with commercial off the shelf vendors

Provide a ride through the TRL "Valley of Death"

Market Interest

- Who cares?
  - Super-Strypi sponsored by the Defense Department's Operationally Responsive Space (ORS)
  - The Airborne-Launch Assist Space Access (ALASA) program sponsored by the Defense Advanced Research Projects Agency (DARPA)
  - The Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS) sponsored by the U.S. Army Space and Missile Defense Command (USASMDC)
  - GOLauncher 2 Generation Orbit Launch Services, Inc. (GO) sponsored by NASA's Launch Services Enabling eXploration and Technology (NEXT) contract

Aggressive technology maturation raises the competitive bar benefiting multiple programs

Risks

- What are the risks?
  - Lack of a dedicated workforce
    - Problems are being solved by students
    - Key personnel are working multiple projects
  - Qualification, certification, and range requirements timeline
    - Most approvals have a fixed timeline that is outside our control
  - Technical risks to cost and shedule
    - Flight termination for new stages (1.5 years and $1.5M)
    - Shroud deployment
    - Nikha pitch over and vehicle attitude control
    - Aggressive stage development schedule
      - NL2A may slip to Oct. or Nov.

Significant risks require robust mitigation strategies

Opportunities

- What are and the potential opportunities?
  - Strengthen inter-center cooperative competition
    - The scale allows multiple paths to be pursued affordably
  - Increased acedemic outreach
    - Redd Hawk Senior Design Challenge
      - 5 projects X 3 schools/project = ~150 students solving our problems
    - Tie into internships, NSTRF, and newhires
  - Improved SBIR/STTR focus
    - Several awards from Nanolaunch topics initiated by Roberto Garcia

A clear, robust vision focuses the efforts of multiple organizations

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Schedule

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- How long will it take?

△ATP △NL2B △Orbital

FY13	FY14	FY15	FY16	FY17
CY13	CY14	CY15	CY16	CY17

△ 1A
Mfg. demo for low cost small solid

△ WFF Trip 3/5/14

△ 2A
4th Stage

Flight Demo
Black Rock, NV

△ 2B (Opportunity)
3rd & 4th Stage
+ WFF Orion. FTS w/RCS & avionics

Flight Demo
WFF

Benefit:
Working relationship
WFF's experience

? Schedule

△ 3A
3rd & 4th Stage
+ WFF Nikha, B Brandt, Terrier w/RCS & avionics

First Orbital Flight
WFF

? Schedule

△NL2A'

FTS development
Shroud development
Re-fly PSRM-30
Dev & Test of PSRM-120
Dev & Test ACS & Telemetry

Demo FTS
Demo Shroud
Re-fly PSRM-30
Demo PSRM-120
Demo ACS & Telemetry
Procure a Boost Motor

Extra flights on balloons or hobby rocket motors for risk mitigation…funding is key to schedule

Final Discussion

- Identify key cost drivers
  - Develop integrated solutions
- A suborbital (NL2b) flight in 2015 will
  - Identify key cost drivers for items other than the propulsion systems
  - Familiarize the team with flight and range operations and procedure
- A defined orbital vehicle with a schedule provides focus and clarity
- Students teams can be used effectively within the critical path

NL1200 Printed LOx/Propane Stage

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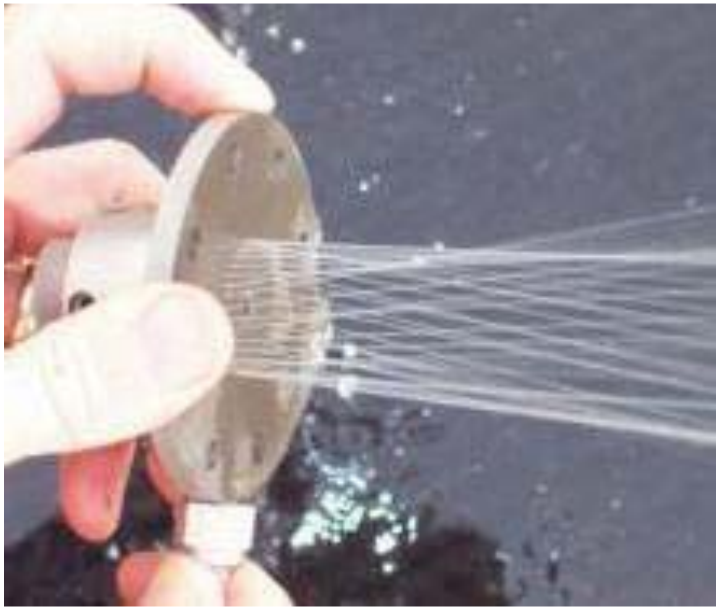
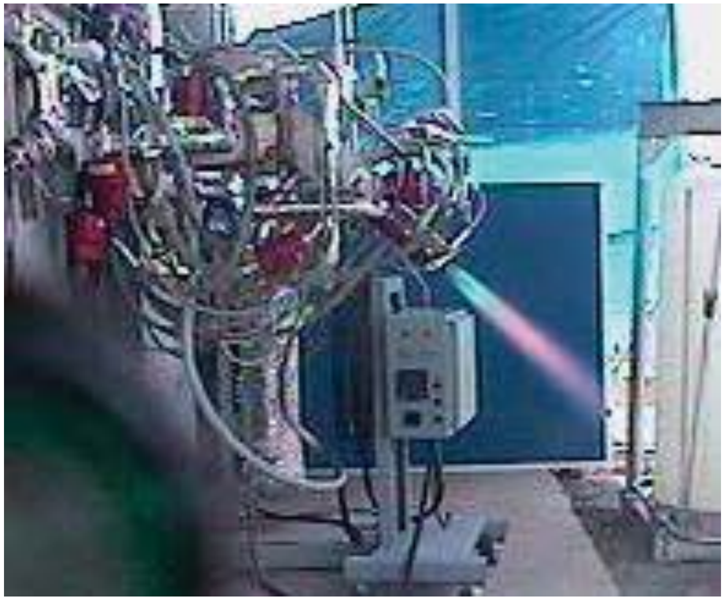
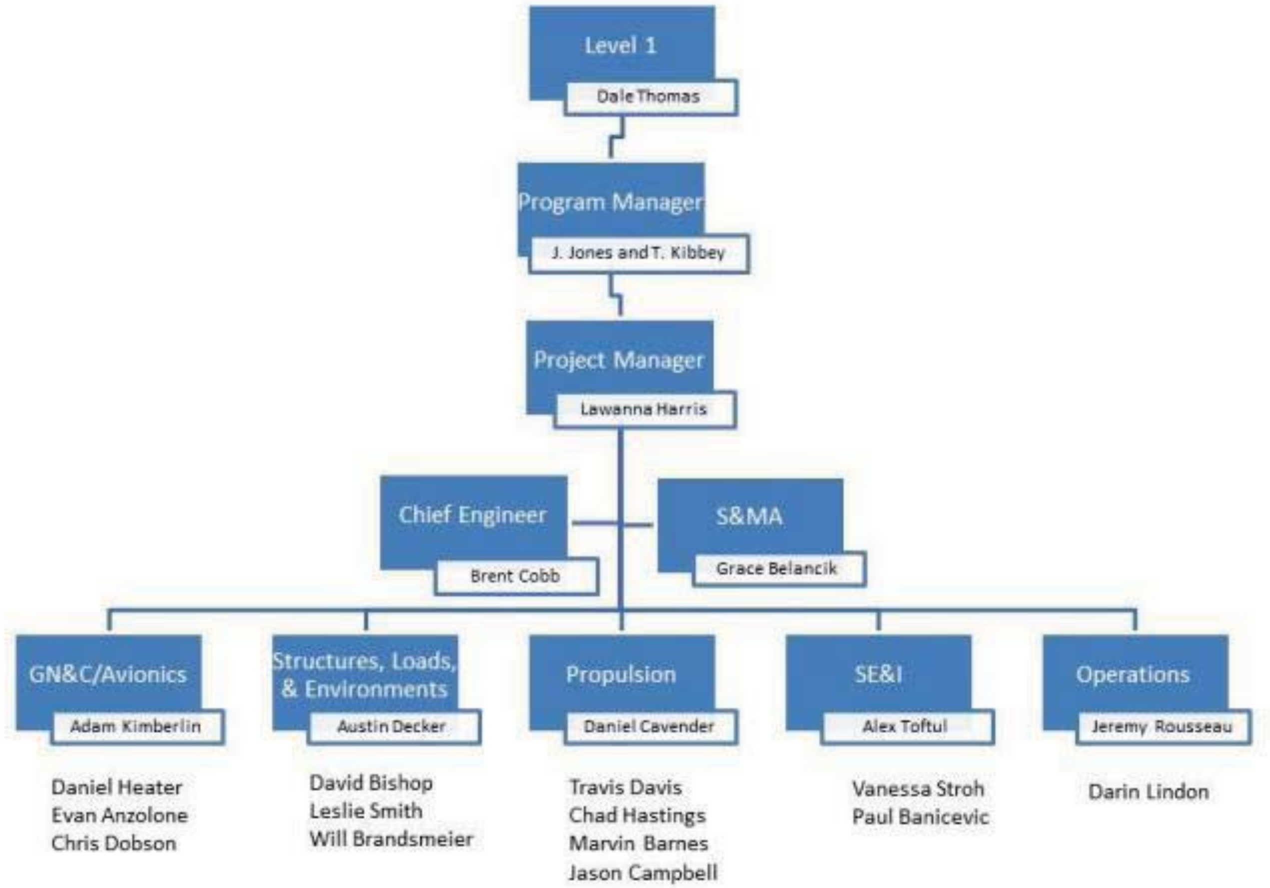
Fill Valve

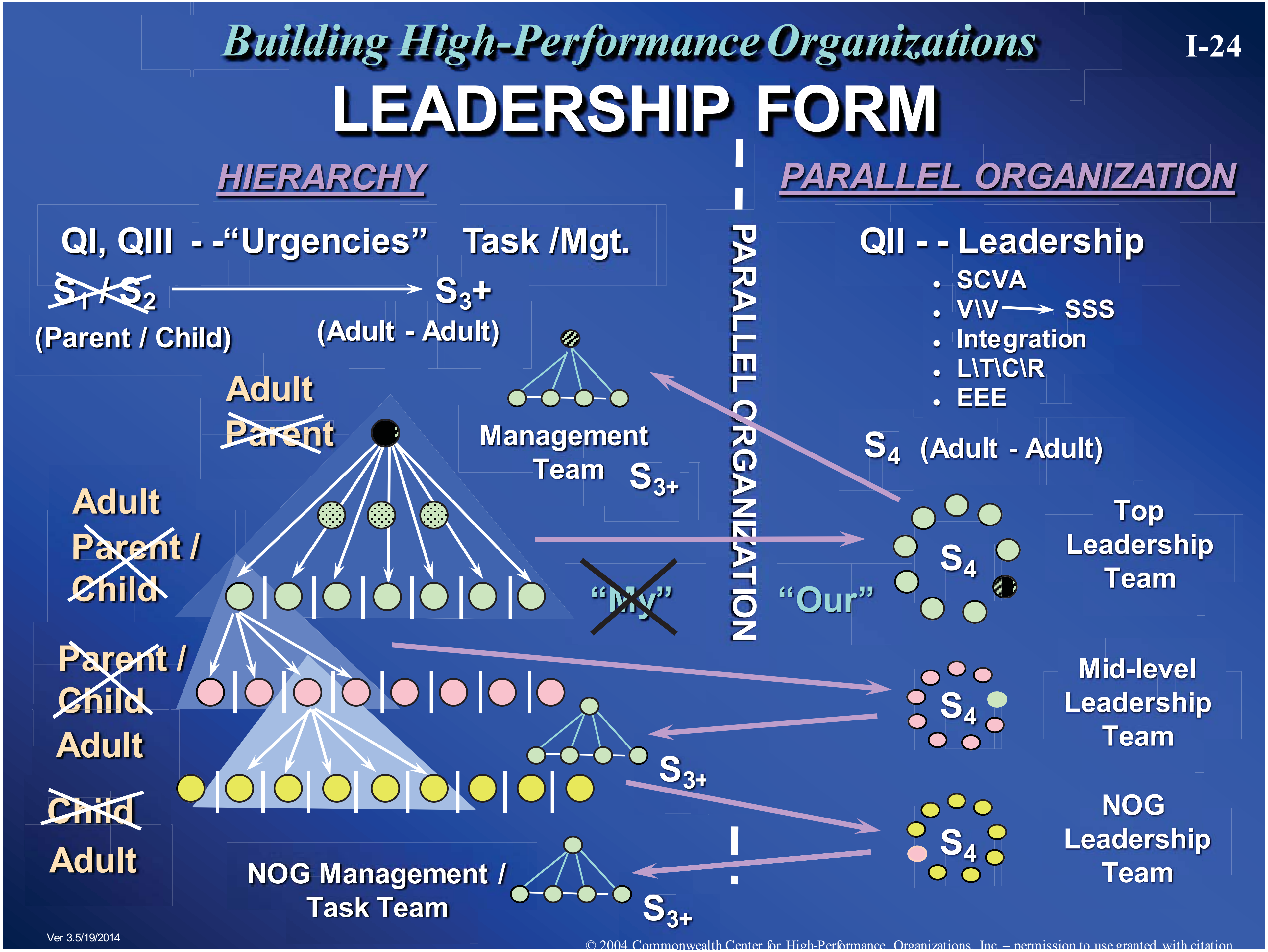
- Static Test of Printed Injector, Nov 2013
- Stage Design
  - NESC Study
  - Auburn University Senior Design Project
- Plug and Play replacement for NanoLaunch 1200 stages
- Performance
  - Thrust ~ Adjusted for stage requirements
  - Isp=330 sec
  - Common uninsulated bulkhead …
- Phase IV stage replacement





Organization





Building High-Performance Organizations
I-24
LEADERSHIP FORM
HIERARCHY
PARALLEL ORGANIZATION
QI, QIII - -"Urgencies" Task /Mgt.
~~S_1 / S_2~~ → S_3+
(Parent / Child)
(Adult - Adult)
Adult
~~Parent~~
Management Team S_{3+}
Adult
~~Parent / Child~~
~~"My"~~
~~Parent / Child~~
Adult
S_{3+}
~~Child~~
Adult
NOG Management / Task Team
S_{3+}
PARALLEL ORGANIZATION
QII - - Leadership
• SCVA
• V\V → SSS
• Integration
• L\T\C\R
• EEE
S_4 (Adult - Adult)
"Our"
S_4
Top Leadership Team
S_4
Mid-level Leadership Team
S_4
NOG Leadership Team
Ver 3.5/19/2014
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