This is a 45min briefing for the IHPRPT Meeting April 6th, 2012.

Briefly introduce yourself and thank the audience members for their interest.

Give briefing objectives:

(1) Explain the SLS current baseline architecture and the SLS block-upgrade approach.

(2) Summarize the SLS evolutionary path in relation to the Advanced Booster and Advanced Development NASA Research Announcements.

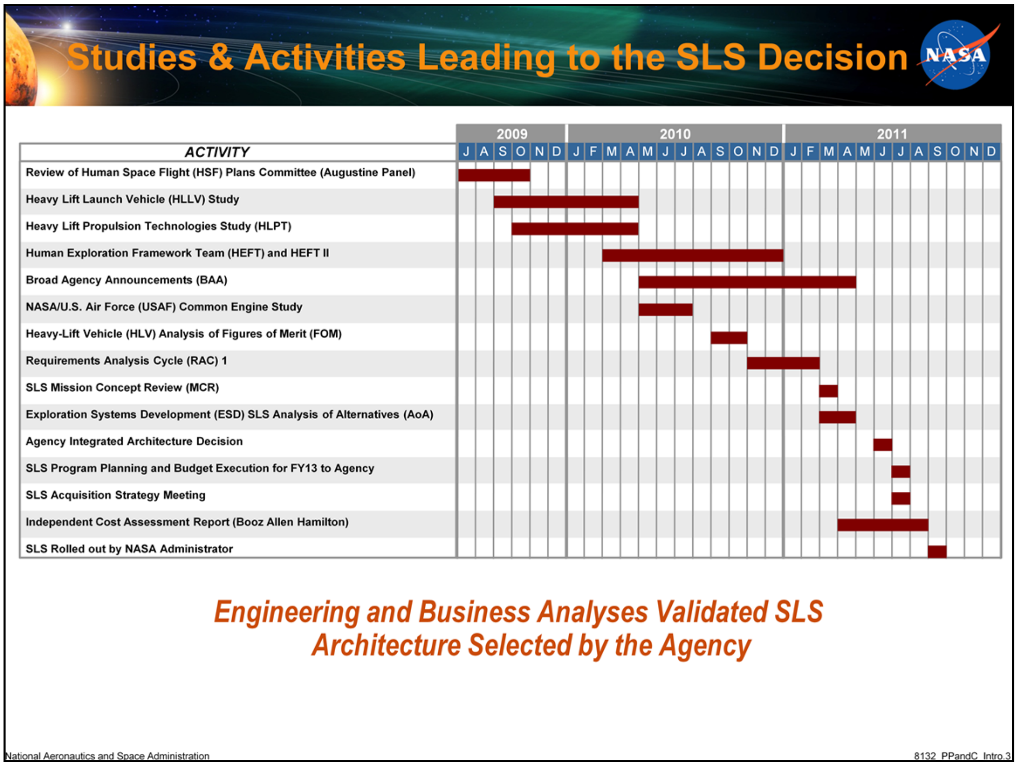
PRESENTER NOTES:

•We used LOX/RP for the Saturn F-1 engines.

•Then the nation made a strategic decision to go with LOX/LH2 for the main engines and solid rocket boosters for the Shuttle.

•The Space Launch System is using heritage hardware from both systems.

•This briefing will give a retrospective on past and relatively current work, as well as show you the SLS plan.



PRESENTER NOTES:

• We have been studying the best replacement for the Space Shuttle for many years.

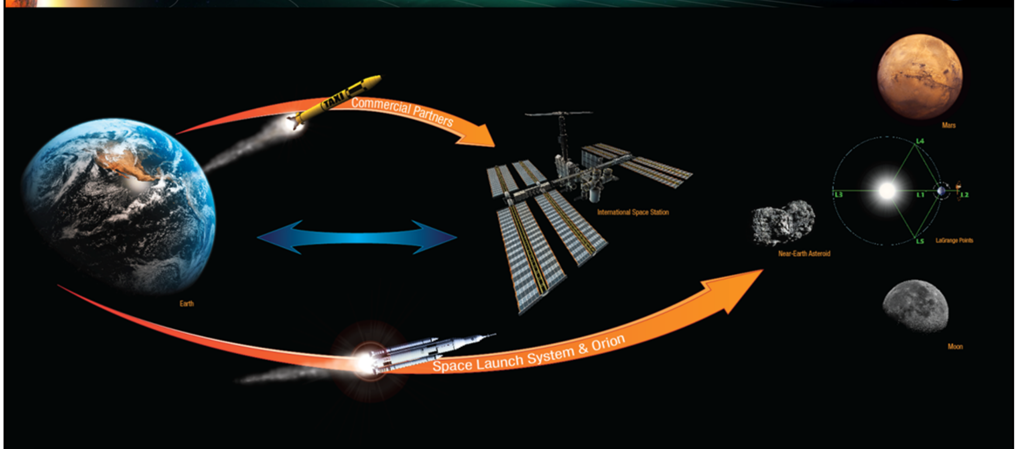
• NASA has participated in many joint studies looking for inter-agency synergies that will lead to mutual solutions for limited budgets.

• This shows a series of studies and activities from 2009 to 2011, when the Agency selected the SLS architecture.

PRESENTER NOTES:

- The SLS is included in the NASA Authorization Act of 2010, so we have some very top-level requirements to meet, primarily to deliver the largest rocket in history on a constrained budget.
- The Agency did its due diligence to arrive at a heavy-lift solution that delivers more performance than the Saturn V for less funding than the Space Shuttle.
- The first SLS rocket is now being built for a first flight in 2017.

The Future of Exploration



My desire is to work more closely with the human spaceflight program so we can take advantage of synergy…We think of the SLS as the human spaceflight program, but it could be hugely enabling for science.

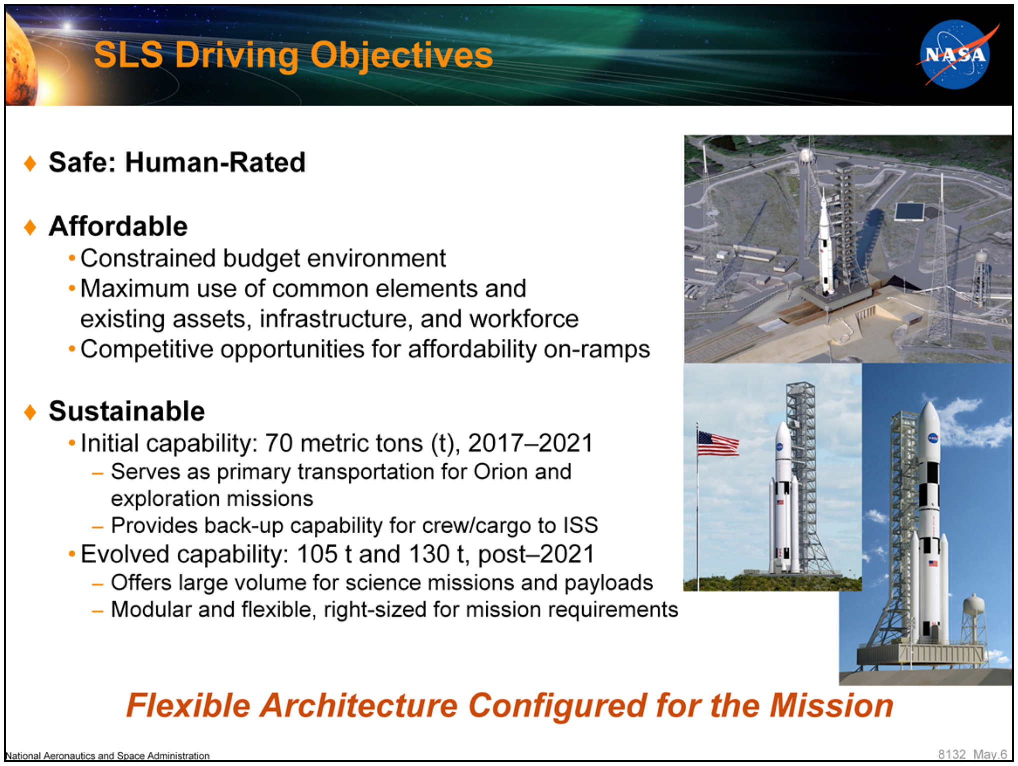
— John Grunsfeld, Associate Administrator
NASA Science Mission Directorate
Nature, Jan 19, 2012

PRESENTER NOTES:

Since we collaborated on the common engine study back in 2010, a lot has happened.

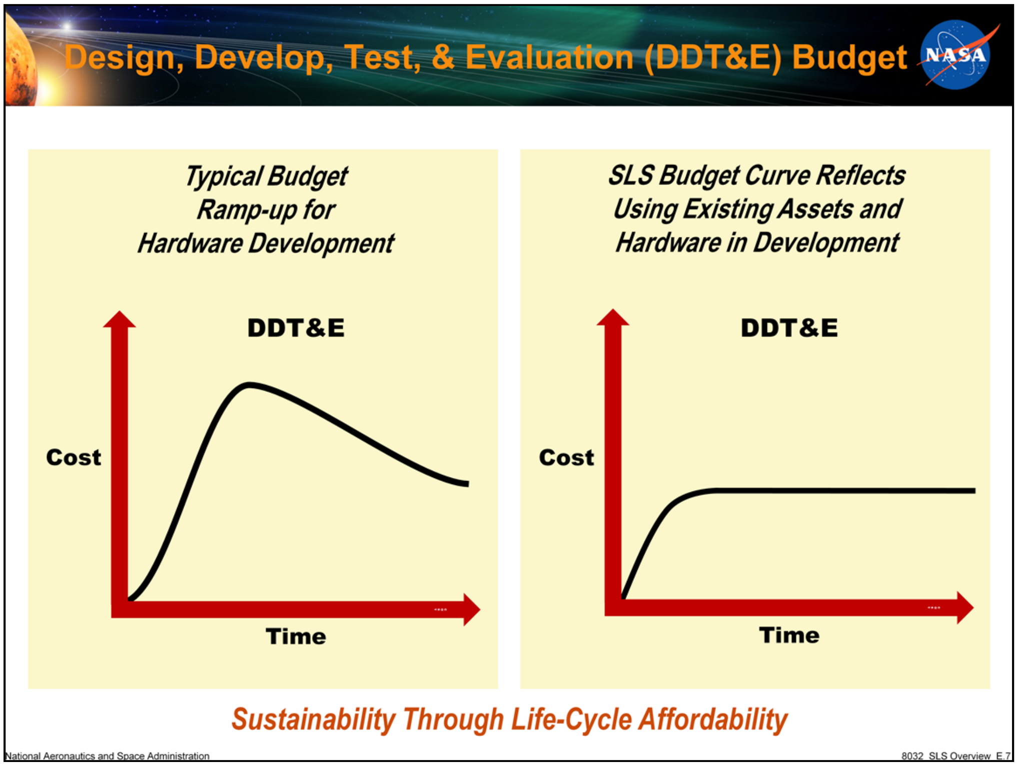
We have started developing the Nation's new capability for human missions beyond Earth's orbit and for new science missions into the solar system.

Give example Design Reference Missions.



PRESENTER NOTES:

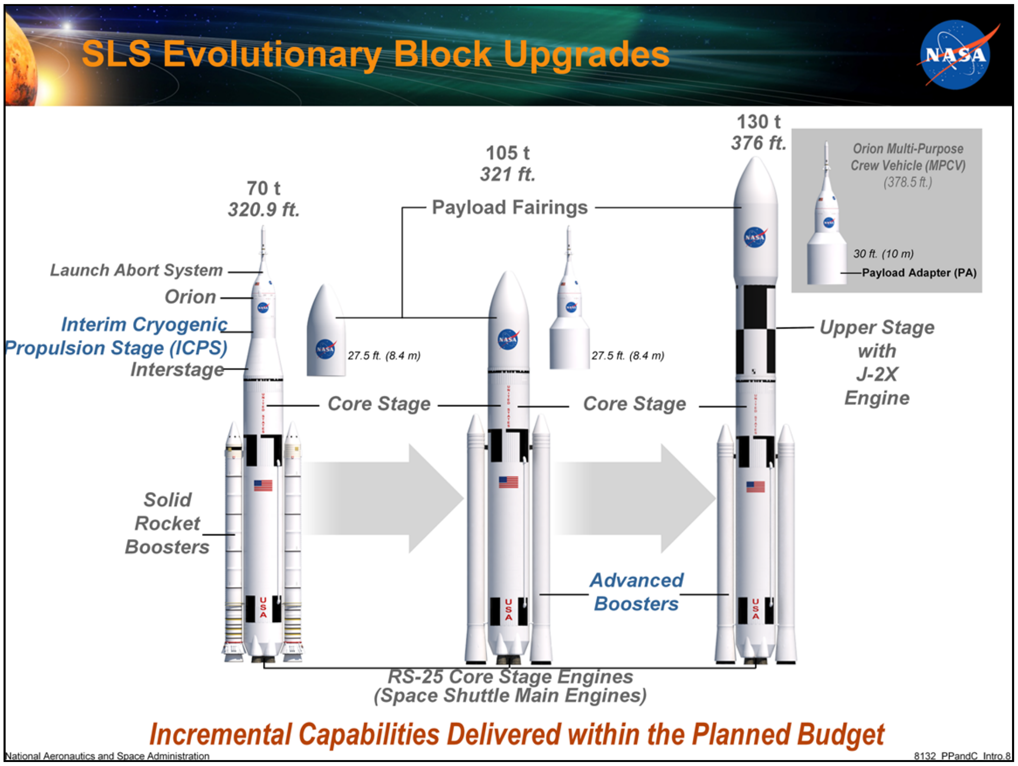
- In order to evolve the SLS configuration to its full 130-t potential, we are phasing development to stay within our budget and to include innovations offered by large and small businesses and academia.
- Affordability goals are being met by starting where we are and making the most of what we have, while giving competitive opportunities for advancing SLS performance in a way that offers the best return on investment for an initial 70-t capability in 2017 and for block upgrades after 2021.



PRESENTER NOTES:

- This configuration and plan maximizes the hard work done by Saturn, Shuttle, and Ares engineers, as well as many others.

- Our budget is phased to keep the curve as flat as possible.



PRESENTER NOTES:

•This shows the 70 t Block 1, the 105 t Block 1A, and the 130 t Block 2 SLS.

•Phasing the development in this way gives near-term solutions for replacing the Space Shuttle, as well as opens the envelope for cutting-edge science missions.

•The stages are the same diameter and will be manufactured using the same materials and processes.

•The boosters for the 70 t initial capability are the most powerful ever built. These 5-segment SRBs are in development testing, as heritage to Ares.

•We do not plan to recover them.

•It is counter-intuitive, but the cost of refurbishing hardware is cost-prohibitive.

•As we evolve the vehicle, we may add liquid boosters, if they prove to be affordable.

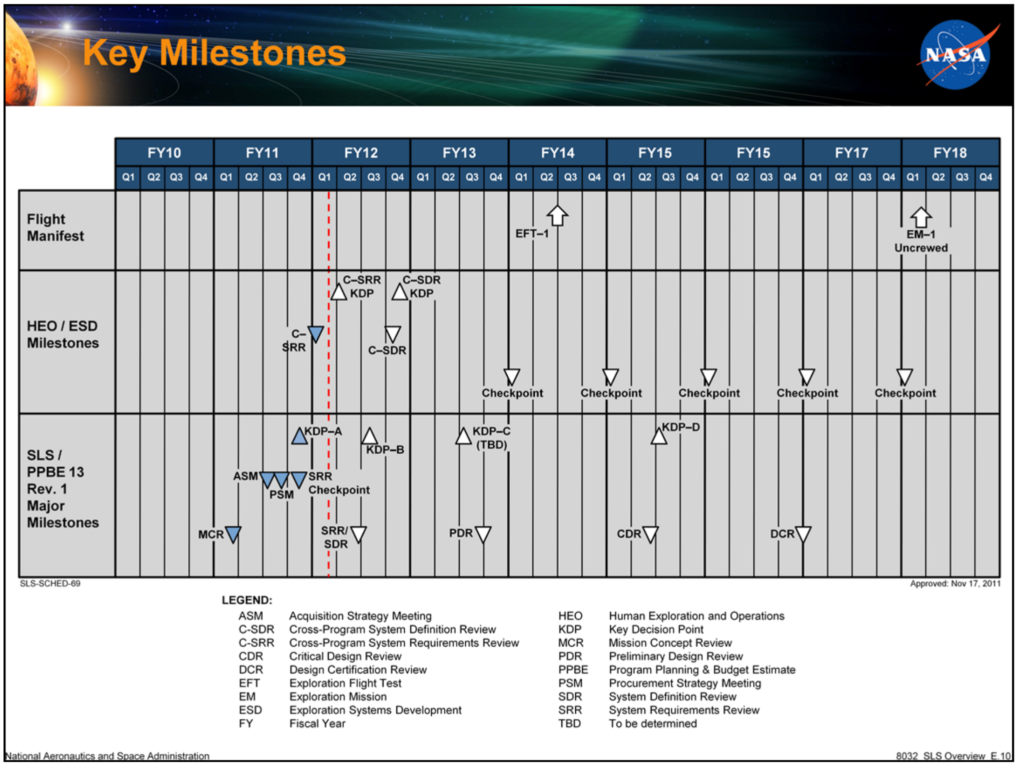
•We have a NASA Research Announcement seeking risk-reduction proposals for advanced boosters and other

•The RS-25 LOX/LH2 core stage engines were designed to be refurbished, but we have 15 in the warehouse, so it would be fiscally irresponsible NOT to use them.

•The J-2XLOX/LH2 engine also is in development testing, also having been brought forward from Ares.

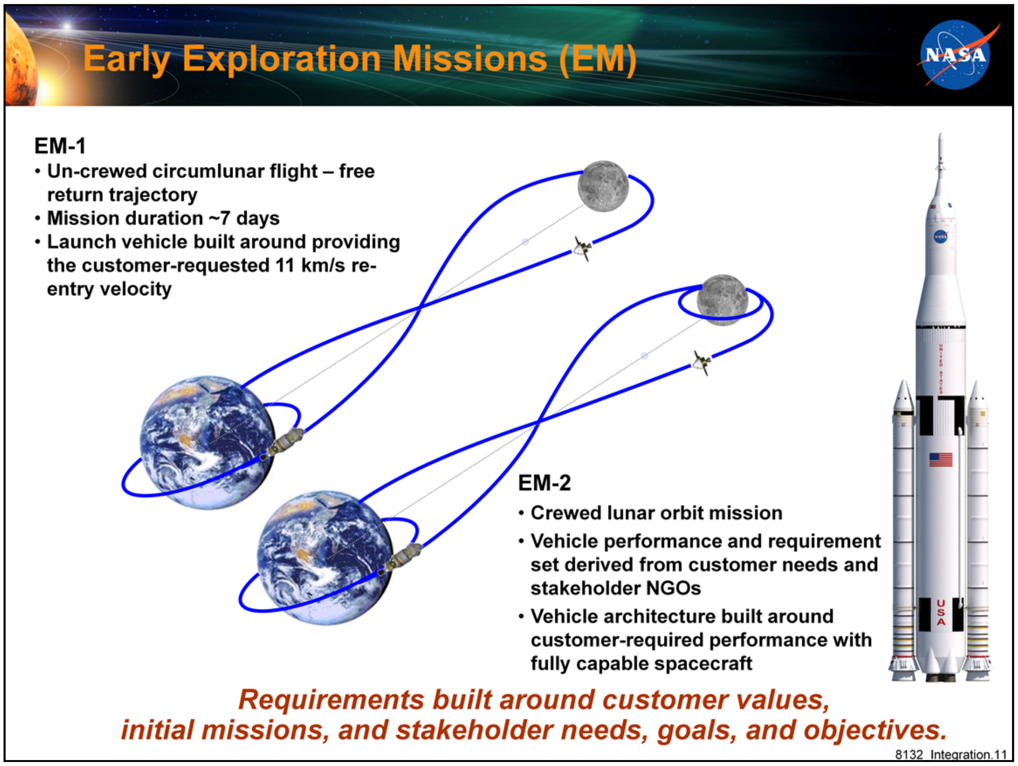
PRESENTER NOTES:

- When we studied the various heavy-lift options against design reference missions and figures of merit, affordability was the dominant factor in our decisions.
- While legacy hardware is an asset from a budget and schedule standpoint, they also present integration challenges.
- But we have a design that gives tremendous performance and that can be developed and operated for the budget we expect to get.



PRESENTER NOTES:

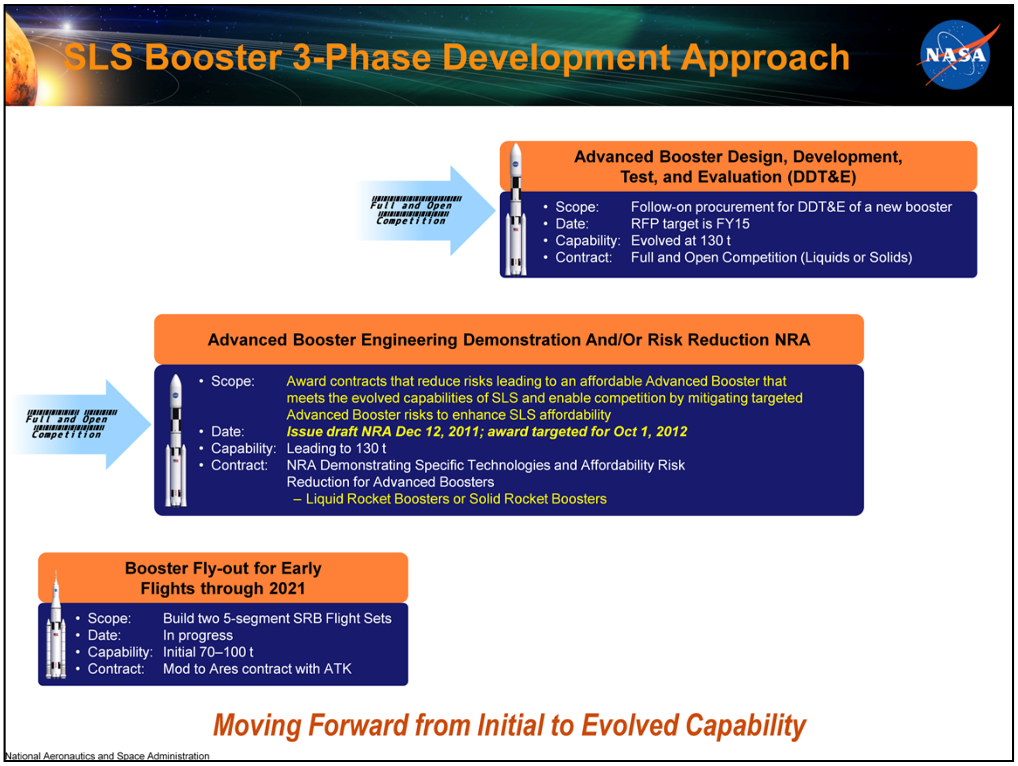
- Because of our development strategy, we feel confident that we can make our milestones and fly in 2017.
- We just kicked off our System Requirements Review and System Definition Review.
- This baselined schedule takes us through our first two manifested flights.



PRESENTER NOTES:

•The SE&I team brings together the various elements and supporting disciplines to make sure we are ready to fly the autonomous Orion mission around the Moon in 2017, followed in 2021 by the first flight of a crew in Orion, also around the Moon.

•The Agency is studying possible science missions to manifest, while we prepare for these first flights.



PRESENTER NOTES:

•To move from the SLS initial 70-t capability to the evolved 130-t variant, will require advanced boosters that are more powerful than any liquid or solid rocket existing today.

Advanced Booster NRA Technical Summary

Requirements relative to SLS vehicle and booster sizing

- **Performance**
  1. **Mass to Orbit - 130 metric tons (286,601 lbm) to LEO**
  2. **Vehicle Dynamic Pressure < 800 psf**
  3. **Vehicle Acceleration < 4.0 g's**
- **Vehicle Configuration**
  4. **Booster-Core Interface**
     - Forward and aft mechanical attach points similar to Space Shuttle
  5. **Booster-Ground Interface**
     - Vehicle mates to 8 mechanical liftoff posts on Mobile Launcher (ML), similar to Space Shuttle
     - Vehicle fits to plume hole on ML
  6. **Load Path**
     - Boosters support vehicle mass / loads (on ML) during assembly, rollout, prep, and tanking
     - Boosters carry bulk of liftoff and ascent loads through forward attach points to the Core
  7. **Height – Booster max height limited to 235 ft based on Kennedy Space Center's Vehicle Assembly Building (VAB) lift constraint**
  8. **Vehicle Width – Core stage + boosters limited to 67.5 ft due to VAB constraint**

National Aeronautics and Space Administration

PRESENTER NOTES:

These slides came from Chris Crumbly's Advanced Booster NRA industry day which is publically available at www.nasa.gov/sls.

Advanced Booster NRA Reference Launch Vehicle

- **Booster mass and propulsion**
  - Liquid – LOX/RP, with six 1M lbf class high-performance hydrocarbon engines

    or
  - Solid – HTPB solid motor thrust trace
- **Core Stage mass and propulsion information**
  - LOX/LH2 with five RS-25E engines
- **Upper Stage mass and propulsion information**
  - LOX/LH2 with two J-2X engines (288k lbf with smaller epsilon nozzle)
- **Non-propulsive payload element**

National Aeronautics and Space Administration

PRESENTER NOTES:

These slides came from Chris Crumbly’s Advanced Booster NRA industry day briefing, which is publically available at www.nasa.gov/sls.

Advanced Booster NRA Reference Missions

- **Launch site – KSC LC-39B (geodetic references, latitude, longitude, altitude)**
- **Ascent description and timeline**
  - Liftoff, pitch/roll maneuvers, gravity turn, propulsion assumptions for tailoff or shutdown, and staging information
- **Ascent environments**
  - GRACE gravitational models
  - GRAM atmosphere and winds
- **Control**
  - Assuming basic 3-DOF trajectory analysis
  - Control authority maintained if control torques remain 2x aero torques due to angle of attack (AoA) and side-slip variations (+/- 8 deg)
- **Guidance (similar to Shuttle)**
  - Open loop prior to booster separation
  - Closed-loop algorithm (PEG) after booster separation
- **Trajectory states**
  - At booster separation
    - Solid: Net booster thrust equals 80,000 lbf
    - Liquid: Propellant depletion
  - At mass injection to LEO
    - -47 x 130 nm orbit at 28.5 degrees inclination, with insertion at 77 nm altitude

PRESENTER NOTES:

These slides came from Chris Crumbly’s Advanced Booster NRA industry day briefing, which is publically available at www.nasa.gov/sls.

Advanced Booster NRA Target Areas

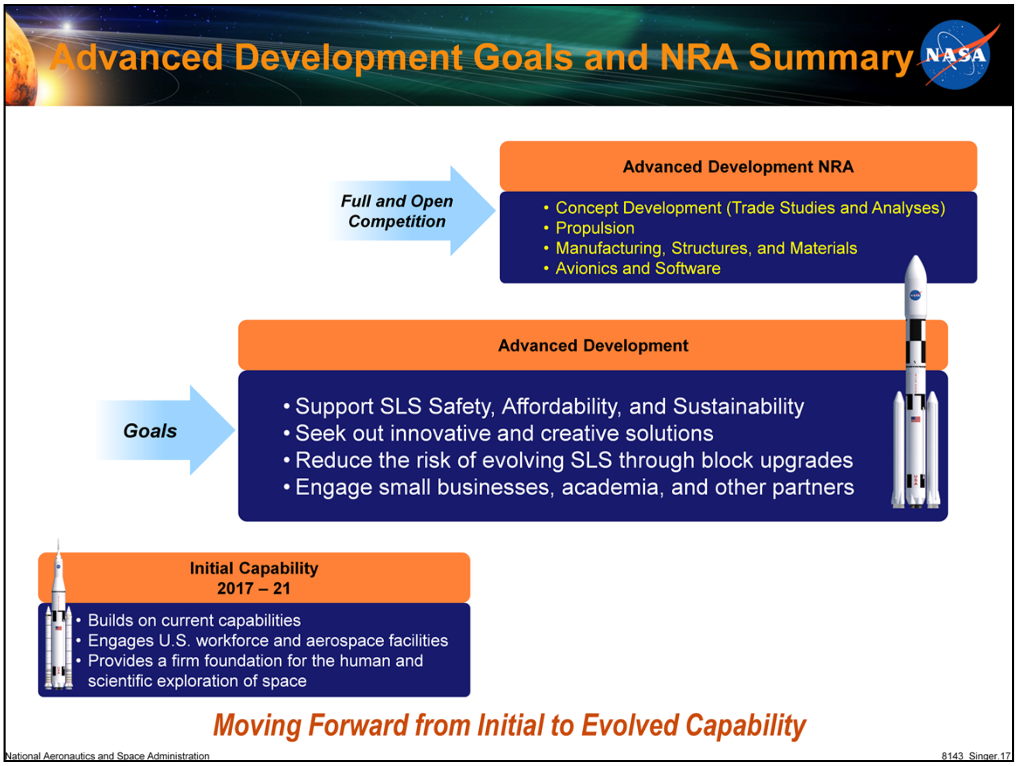
Notional Target Areas for Engineering Demonstration and/or Risk Reduction
Large Booster Component Development/Fabrication
Modular/Common Booster Component Development/Fabrication
Oxygen-Rich Materials/Technologies Development
Refined Petroleum (RP) Combustion Performance and Stability Advancement
Potential Recovery and Reuse of Salt Water Recovered Engines and/or Booster Systems
Structural Testing of Low Mass-to-Strength Ratio Material
Non-Destructive Evaluation of Low Mass-to-Strength Ratio Material Structures
Damage Assessment of Solid Propellant/Liner/Insulation Integrity (during fabrication up until launch)
Solid Booster Propellant Formulations
Advanced Manufacturing Process Demonstration
Advanced Material Selection and Test
Thrust Vector Control (TVC) Systems/Components
Booster-to-Core Interface Attach Point Methods/Locations

SLS Is Open to All Potential Solutions

National Aeronautics and Space Administration

PRESENTER NOTES:

- Multiple awards are anticipated.
- Total funding available: $200 million
- Funding allocation: 30% in FY2013; 50% in FY2014; and 20% in FY2015
- Period of Performance: October 2012 – March 2015.



PRESENTER NOTES:

One of the key ways for the Program to be affordable is to achieve a successful first launch in 2017 with the initial 70 metric ton vehicle, then evolve to the 130 t capability as the program progresses.

Program has organized such that the advanced development work is managed by the Advanced Development Office.

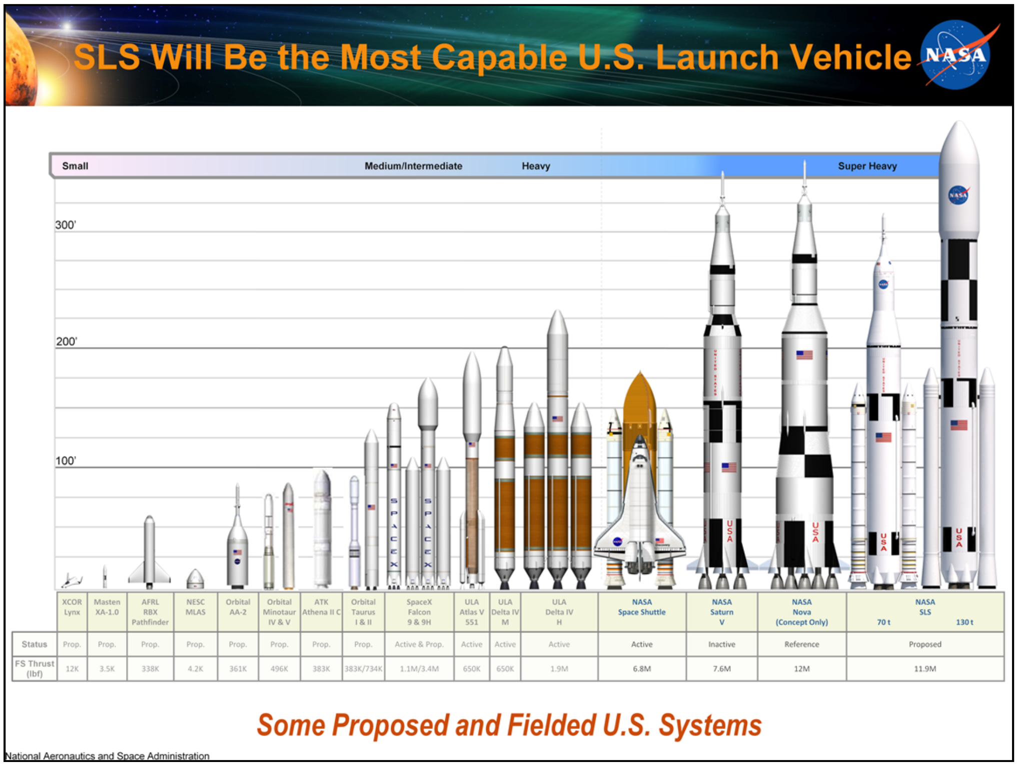
This organizational structure provides the flexibility to tactically focus on the first launch in 2017 with the 70 metric ton vehicle and to allow the advanced development activities to be done in such a manner as to not distract from the initial launch in 2017.

The Advanced Development NRA total anticipated funding available is $40 million:

- o Anticipated Funding split:

FY2013	Industry $18.5M, Academia $1.5M
FY2014	Industry $ 8.5M, Academia $1.5M
FY2015	Industry $ 8.5M, Academia $1.5M

- Period of performance is a 12-month base period, with two 1-year options.
- Multiple awards are anticipated.
- **Includes investment by U.S. Air Force, Space and Missile Systems Center, for technologies applicable to the Affordable Upper Stage Engine.**



PRESENTER NOTES:

- The SLS will deliver an unsurpassed capability.
- The country has a range of launch vehicles from which to choose.
- The SLS is a platform for America’s continued leadership in space.

NASA's Space Launch System Summary

- **SLS is vital to NASA's exploration strategy and the Nation's space agenda.**
- **SLS key tenets are safety, affordability, and sustainability.**
- **We are currently conducting the System Requirements Review/System Definition Review.**
- **Prime contractors have been selected and UCAs have been signed, engaging the U.S. aerospace workforce; Government/contractor Integrated Acquisition Team validation is in progress.**
- **Existing hardware (RS-25 core stage engines) is being positioned for integration and testing with the core stage.**
- **Advanced hardware testing (five-segment solid rocket boosters and J-2X upper stage engine) is in progress.**
- **Competitive opportunities for advanced boosters and developments that support affordable performance upgrades are in progress.**
- **SLS design and development is on track for first flight in 2017.**

National Aeronautics and Space Administration

8032_SLS Overview_E 19

PRESENTER NOTES:

- SLS is a national asset that complements the payload delivery capabilities of our commercial space partners. We need both to be successful.
- The SLS value proposition is missions of national importance, delivering more capacity and thrust than any past, present, or otherwise planned vehicle for entirely new missions beyond Earth orbit.
- We are focused on the rocket as the product.

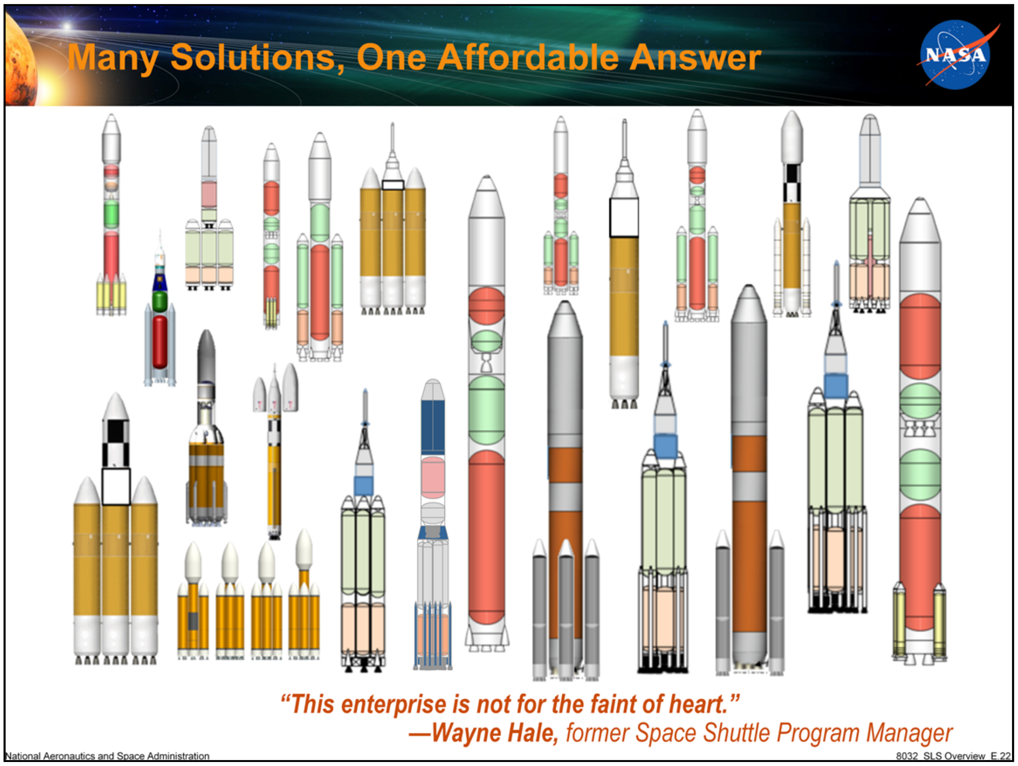
For More Information

www.nasa.gov/sls

PRESENTER NOTES:

- Please visit our website for the latest SLS news.


National Aeronautics and Space Administration
NASA
Back Up Information
Space Launch System
www.nasa.gov



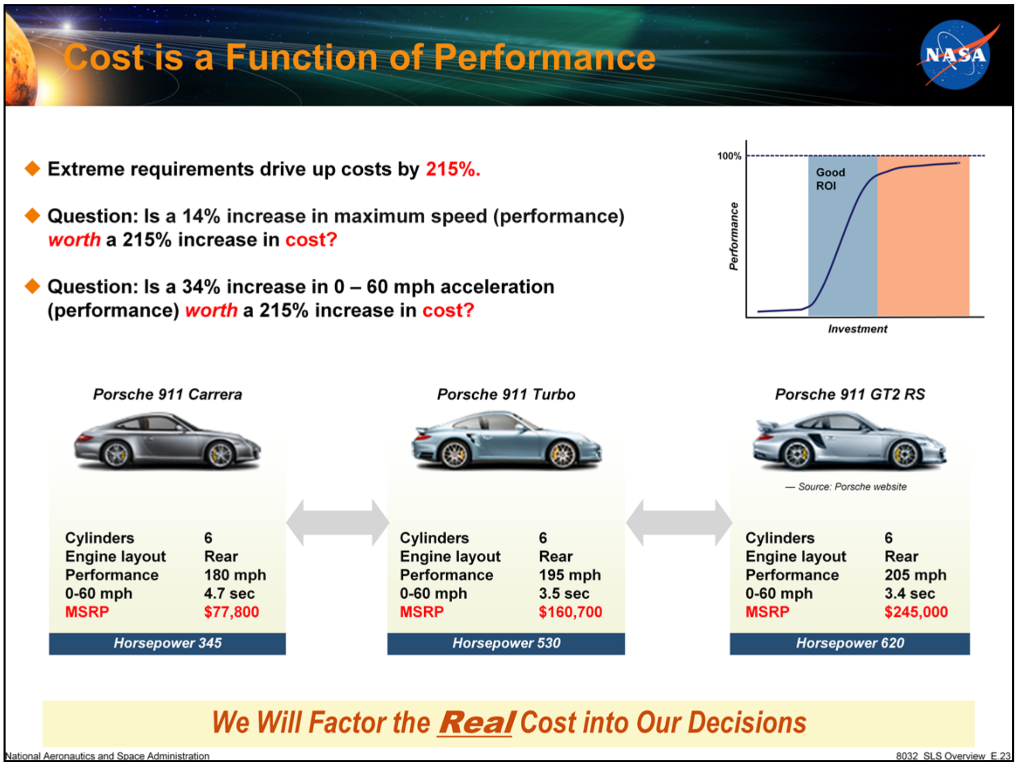
PRESENTER NOTES:

http://waynehale.wordpress.com

- We studied literally thousands of concepts over the past decade.

- We measured those concepts against NASA's requirements to take astronauts beyond Earth orbit.

- The concept that the Agency selected is the optimal one for safety, affordability, and sustainability. It uses a mix of available engines assets and hardware already in development to meet a first flight date of 2017 and an evolved capability after 2021.

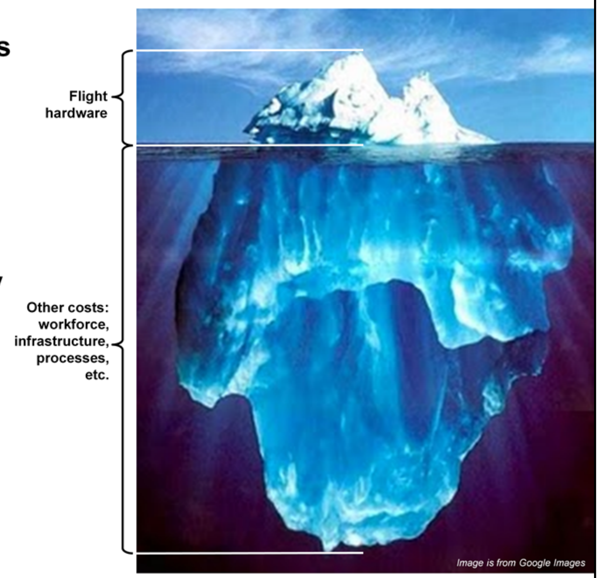


PRESENTER NOTES:

- We will not chase performance. We will have ample margin to allow us to solve challenges that naturally arise during an engineering feat of this magnitude.
- Our decisions will factor not only performance outcomes, but the return on investment.
- There has been a lot of talk about cost as an independent variable, and SLS will be implementing that philosophy.

The Real Cost of Launch Vehicle Development

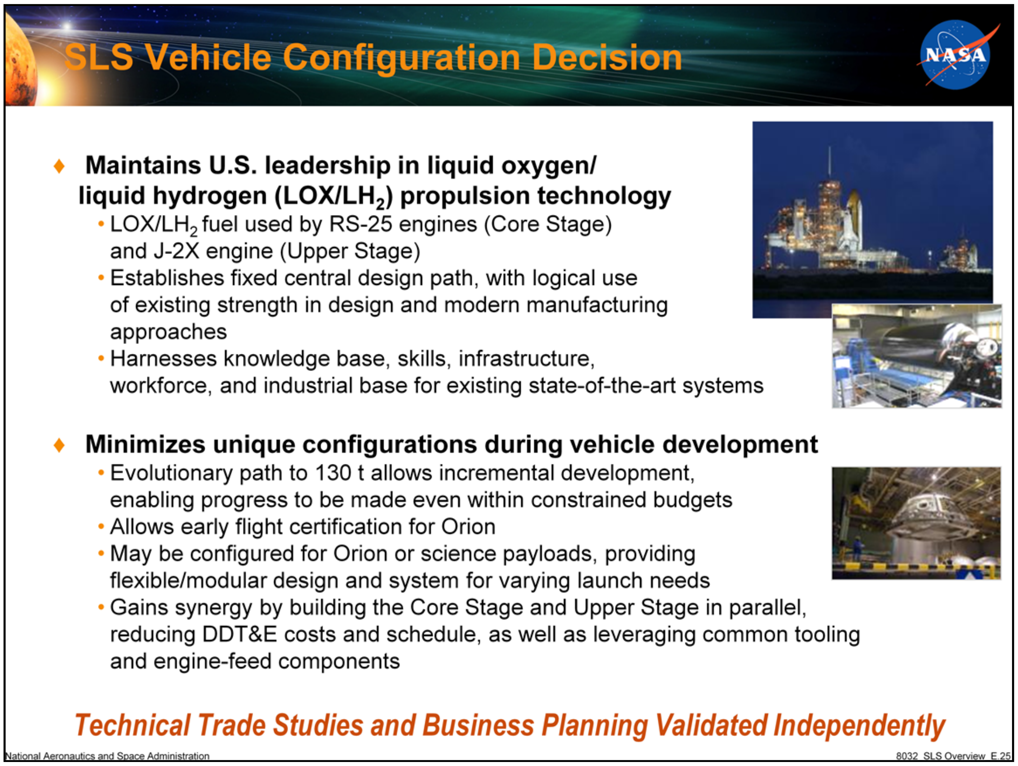
- Affordability requirements demand that we develop the SLS in a faster and more efficient manner, including the decision-making process.
- We cannot afford to delay decisions … or delay getting behind them!



Time Is The One Resource That We Can Never Regain

PRESENTER NOTES:

- We all face this reality every day.
- Getting a decision is hard. Getting everyone behind the decision is harder.
- There are a lot of things over which we have no control; this is where we have control.
- Make no mistake, delaying a decision or failing to get behind a decision costs the Agency and the taxpayer millions of dollars each day.
- That is a sobering fact that colors the way we think, relate, and act.



PRESENTER NOTES:

- The Agency carefully studied options and made decisions based on fulfilling policy and law, combined with the optimum approach to support the U.S. aerospace industry's talented workforce and unique infrastructure.

- This choice fits within the budget box in the near term and long run.

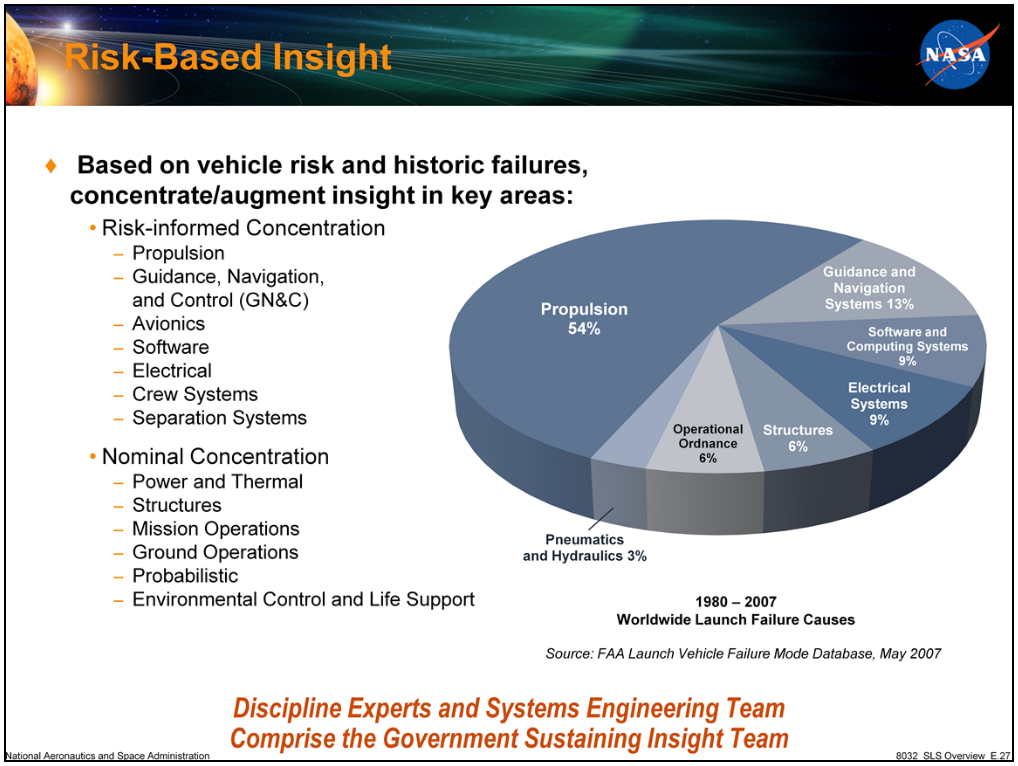
- It reflects a strategy that builds on the best of our investment base and helps create a stronger aerospace platform in the process.

PRESENTER NOTES:

We are identifying the workforce, infrastructure, and assets that will be vital to our success as we go forward.

These images show:

- *J-2X Upper Stage Engine Test Firing/Space Shuttle Main Engine Testing (SSC):* Top half is J-2X engine test firing. Bottom half is SSME testing.
- *Payloads (GSFC):* Hubble Space Telescope
- *Orion Integration (JSC):* Orion spacecraft component
- *Composite Structure (GRC):* Ares composite payload fairing
- *Ground and Launch Operations (KSC):* Launch pad 39A
- *Physics-Based Analysis (ARC):* Blast debris field modeling for the *Columbia* accident
- *Manufacturing and Transportation (MAF):* A barrel section for the Space Shuttle External Tank
- *Wind Tunnel Testing (LaRC): Ares* I model
- *Standing Review Team (JPL):* Mission concept review report card
- *J-2X Upper Stage Engine Injector Test Firing (MSFC):* J-2X engine injector test firing



PRESENTER NOTES:

- To get us thinking about where we need to put our resources, we are conducting benchmarking studies with successful business like Apple, Boeing Aircraft, and others to help focus our energies and investments.

- With much real-world data on which to draw, we will vector our insight levels and interfaces.

- We will also use industry standards where appropriate and minimize the number of formal deliverable documents.

PRESENTER NOTES:

- The primary mission for the SLS is to take human explorers beyond Earth orbit, but it also will provide backup transportation services to the International Space Station.

- This is a demanding business, both programmatically and technically.

- The Space Station is an example of how to manage a major engineering undertaking from one Administration to the next.

- It has persevered because **America's leadership in space is a national priority.**

- The Space Station has spurred markets. For example, the Japanese and Europeans routinely send autonomously operated cargo vehicles there, and NASA is helping private industry develop valuable logistics capabilities for both crew and cargo.

- The Space Station reflects the power of international collaboration that will serve as a model for future exploration missions.

- The Space Station has shown that opportunities for collaboration will highlight our common interests and provide a global sense of community.

- It is where we can learn to survive in the harshest environment imaginable and where astronauts are preparing today for the next big leap in American space exploration.

PRESENTER NOTES:

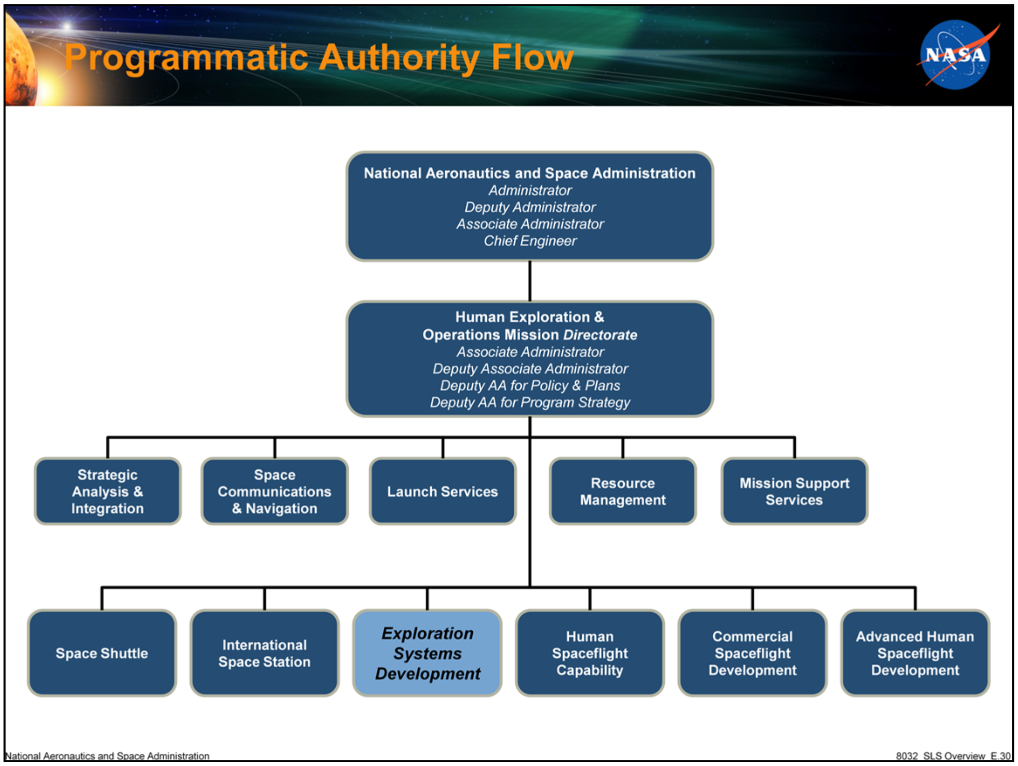
The Marshall Space Flight Center hosts the SLS Program, offering core competencies in program management, systems engineering, materials science, and propulsion.

We were set up as a planning team in December 2010 and made a full-fledged program office in March 2011.

We bring a mixture of scientific and human space flight experience, both development and operational, to one of the hardest jobs being undertaken on this planet at this time.

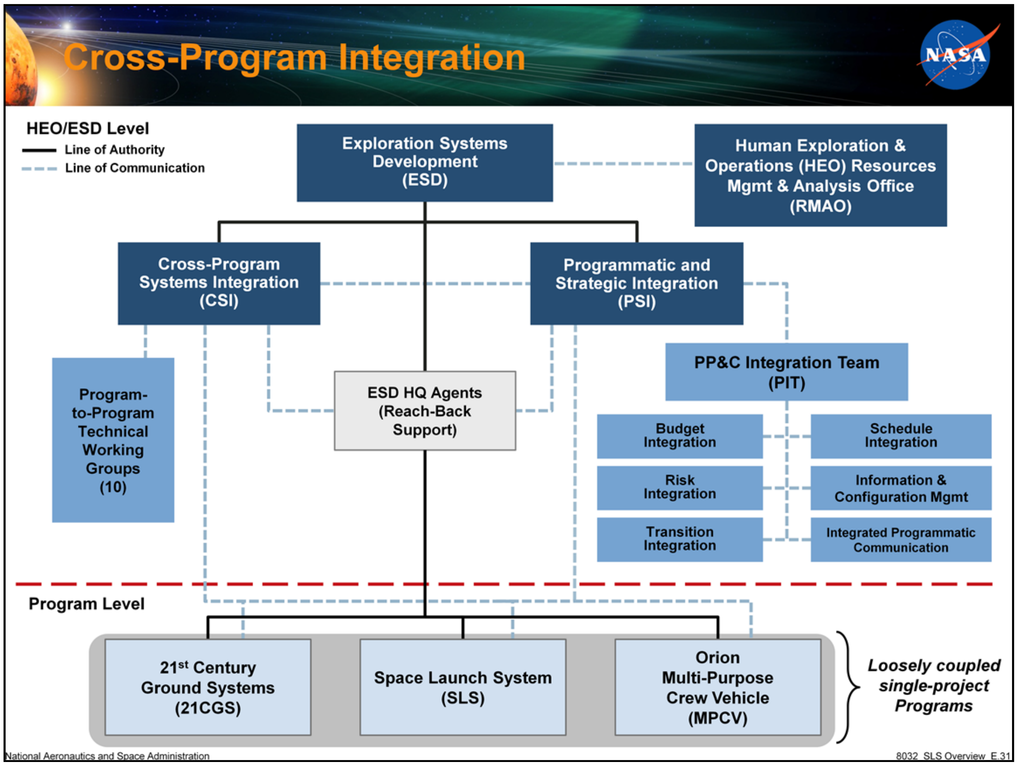
Fifty years of experience inform our decisions, and the talent that it takes to do this very hard job is here today.

We have an open-door policy and want to hear from you.



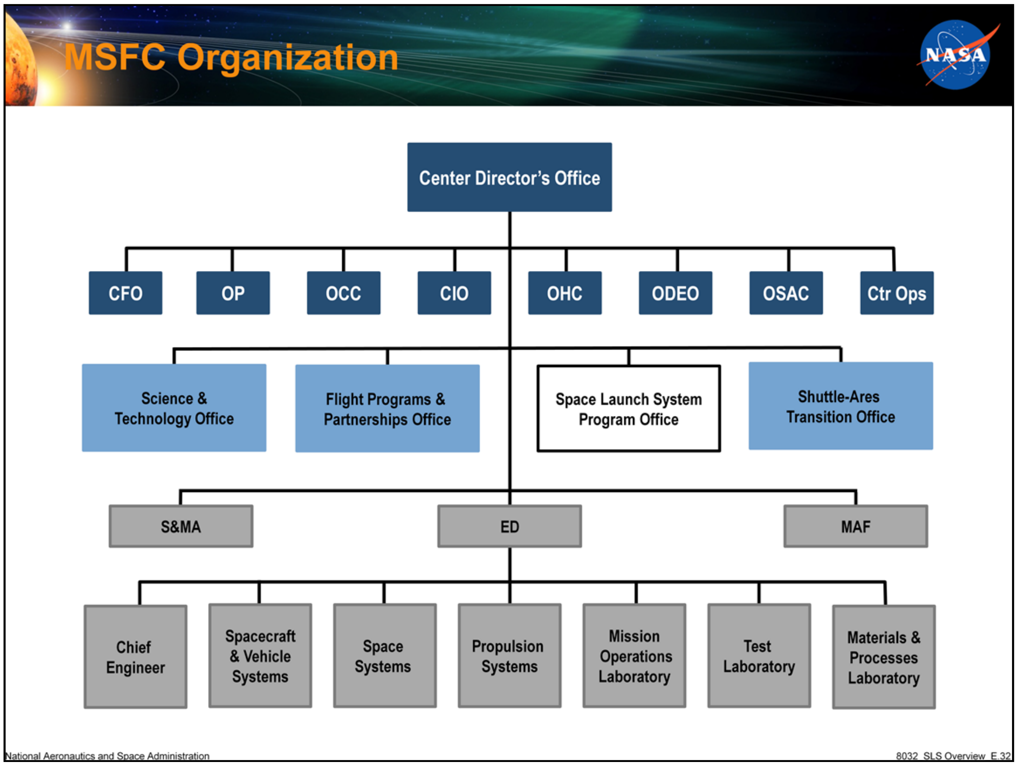
PRESENTER NOTES:

- Here is how we fit into the bigger picture within the NASA system.



PRESENTER NOTES:

- This is our primary customer base.
- We have great leadership and are well integrated with our partner programs, Orion Multi-Purpose Crew Vehicle and 21st Century Ground Systems.
- This is how our requirements and funding flow down.
- We have a direct link to NASA Headquarters, unlike Ares before us.



PRESENTER NOTES:

- SLS is a relatively small office for a billion-dollar annual effort.

- We depend on our partnerships with Marshall and the other NASA Centers to deliver technical excellence, on time, and within budget.

- We are collaborating with industry to arrive at the best value for the taxpayers investment.