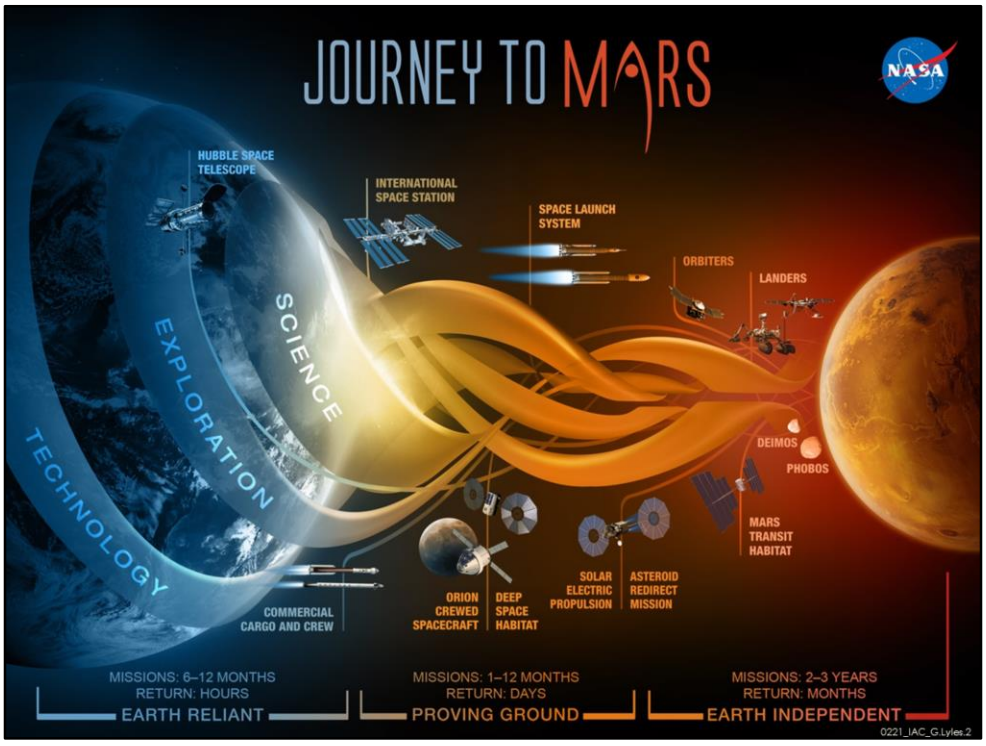
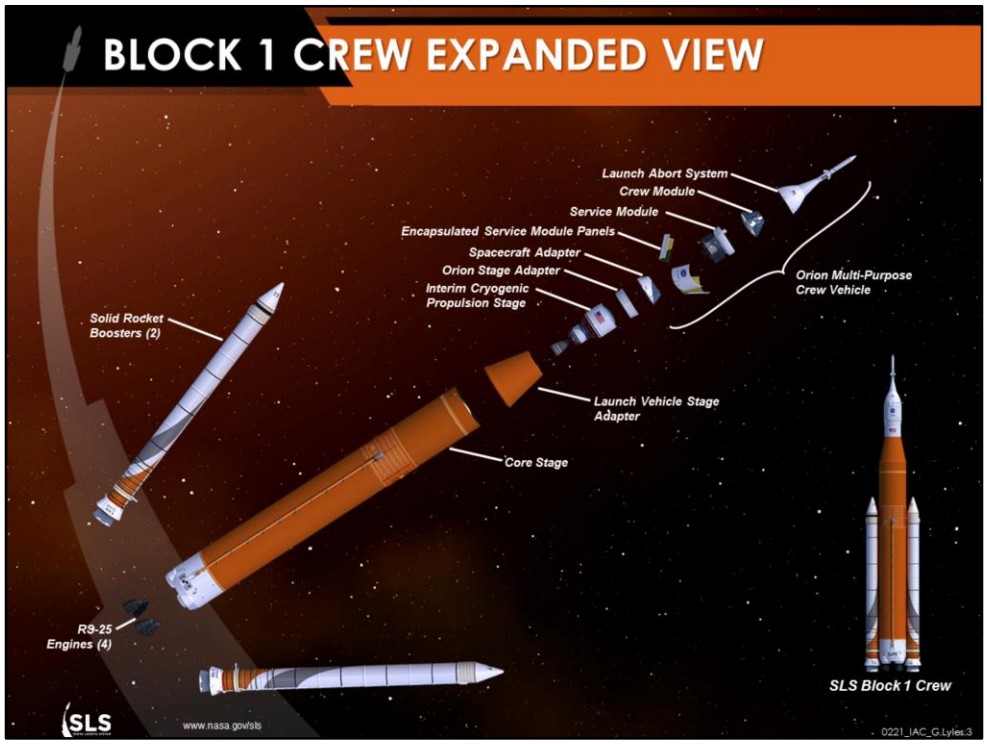
- **Welcome**
- **Exciting time to be in the space exploration business.**
- **This presentation will cover technical progress on NASA's Space Launch System.**
- **This is no longer a paper rocket. We are making real progress, building real hardware.**

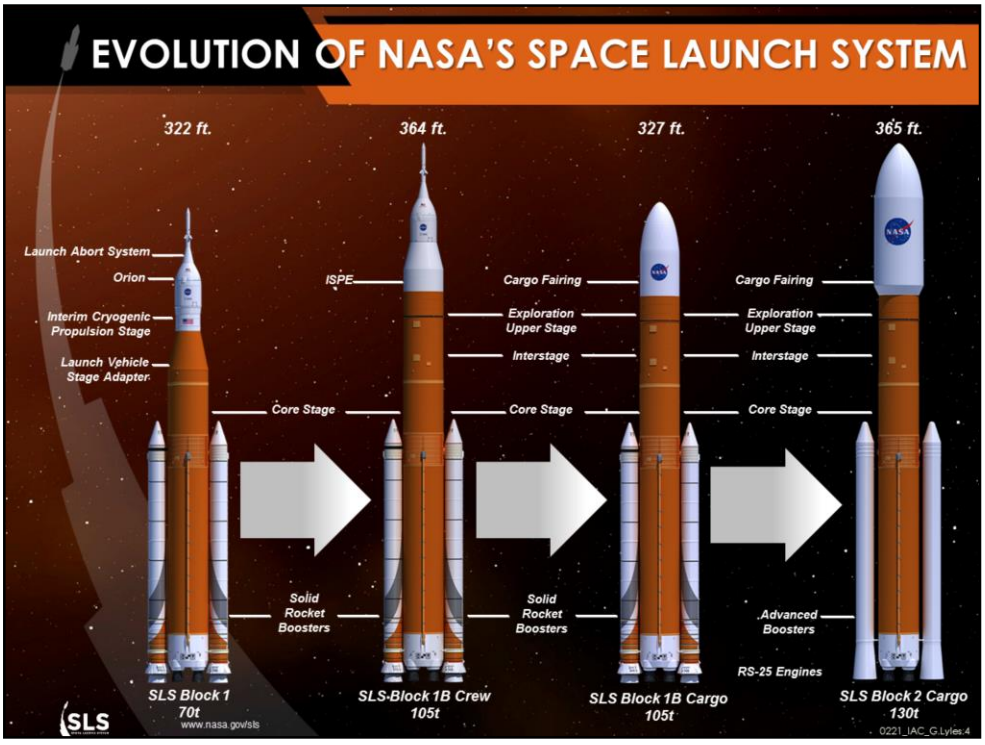


- **I'd like to start with how SLS fits into the nation's future exploration plans.**
- **This famous chart encapsulates the roles of science, exploration, and technology, the major components of exploration, and the increasingly independent regions of operation.**
- **Incorporates International Space Station and commercial crew and cargo partners, robotic exploration of Mars, the cis-lunar or "Proving Ground" missions, and ultimately the "Mars Ready" or "Earth Independent" region.**
- **Emphasis now on Phase 0-2 activities:**
    - **Phase 0: Exploration Systems testing on ISS**
    - **Phase 1: Cis-lunar flight testing of exploration systems (crewed asteroid retrieval marks the end of this phase)**
    - **Phase 2: Cis-lunar validation of exploration capability (**

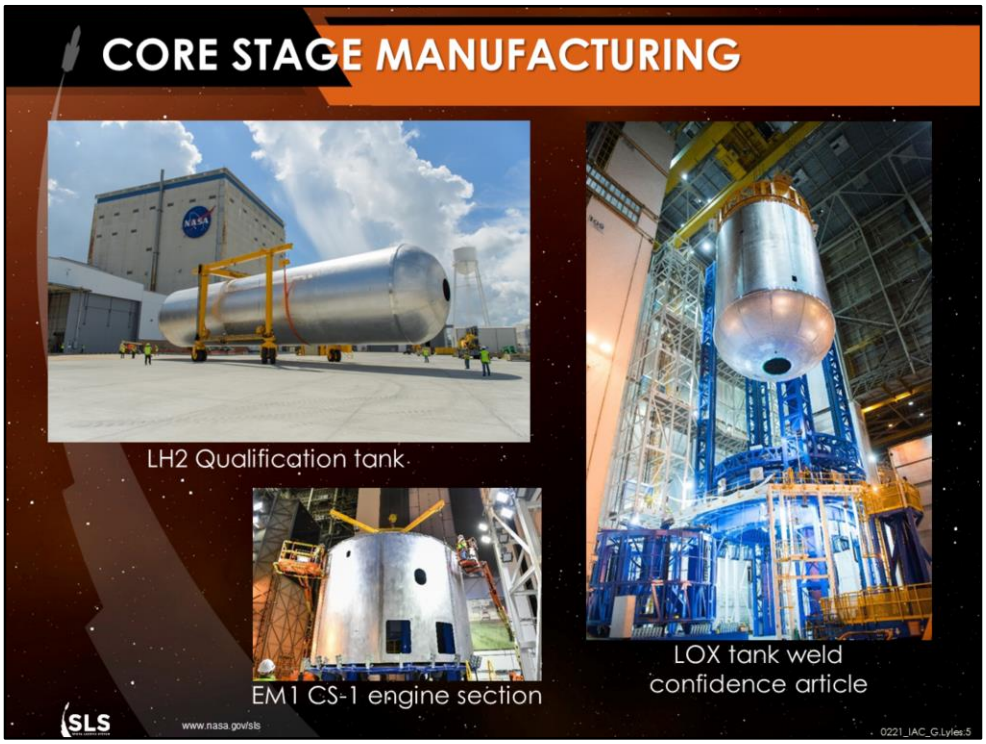


- **Stood up SLS program in 2011 and progressed now from development into production of the most capable launch vehicle in the world – with a path to evolve it to the most powerful rocket in history.**
- **Focus now on initial capability SLS shown here – Block 1.**
- **322 foot tall, 27.6 foot diameter core stage, 177 foot tall boosters**
- **Affordability was a key metric in the design shown here and behind the scenes in streamlining our facilities and processes.**
- **Shuttle ET diameter core stage, conventional 2219 aluminum.**
- **Adapted shuttle RS-25 engines, high performance, large experience/industrial base, 16 available engines.**
- **5-segment solid rocket boosters, shuttle/Ares heritage, 75% of liftoff thrust.**
- **Interim Cryogenic Propulsion Stage, modified Delta Cryogenic Second Stage, RL-10B2 engine.**
- **EM-1 mission, 2018, un-crewed Orion test flight, 13 secondary payloads/cubesats, many related to future exploration.**
    - **Lunar studies: Lunar Flashlight (NASA), Lunar IceCube (Morehead State University, KY), LunaH-Map (Arizona State University), Omotenashi (JAXA)**
    - **Asteroid studies: NEA Scout (NASA)**
    - **Solar studies: CuSP (Southwest Research Insititute)**
    - **Earth studies: EQUULEUS (JAXA), Skyfire (Lockheed Martin)**
    - **Biological studies: Biosentinel (NASA)**
    - **ICPS: ArgoMoon (ESA/ASI)**

- **TBD: Three Centennial Challenge selectees**

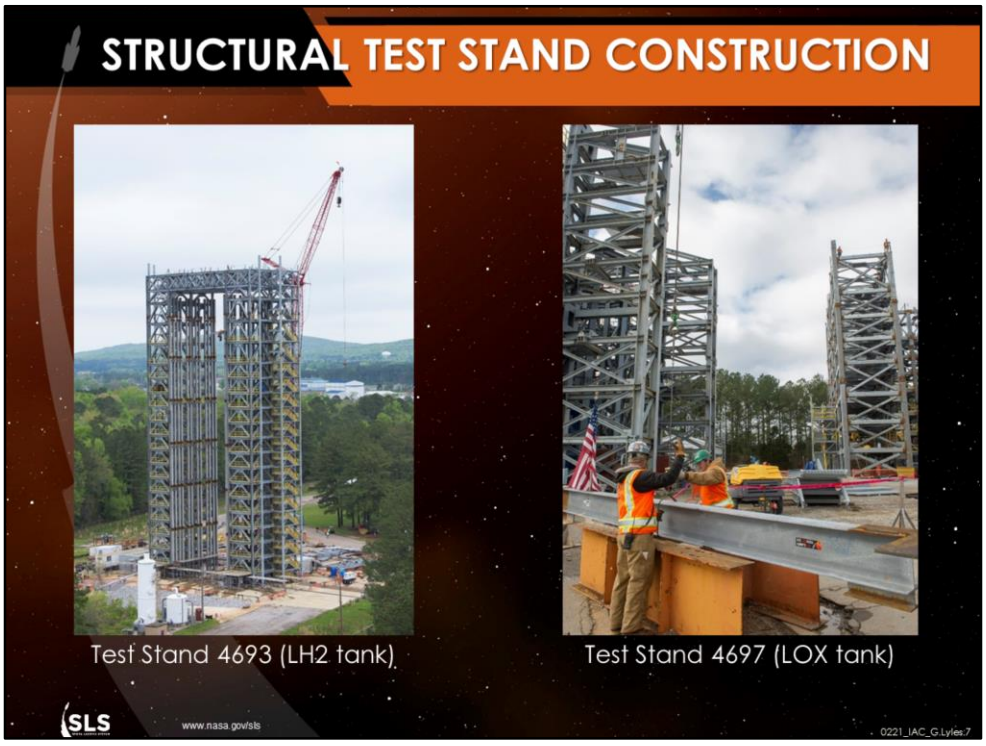


- **Vehicle architecture designed to evolve**
- **Crew and cargo variants**
- **Future enhancements, Exploration Upper Stage, increased RS-25 thrust, more powerful boosters, larger payload fairing**
- **Plan to begin flying Block 1B vehicle on EM-2**
- **Evolved SLS enables: Europa probe, sample return missions from outer planets, cis-lunar habitats and landers, crewed Mars missions.**
- **SLS/heavy lift buys down risk on the ground instead of space**
    - **Minimum mass for 4-crew Mars surface estimated at over 500t**
    - **SLS reduces launches, in-space assembly, assembly time, payload design complexity, known technology**

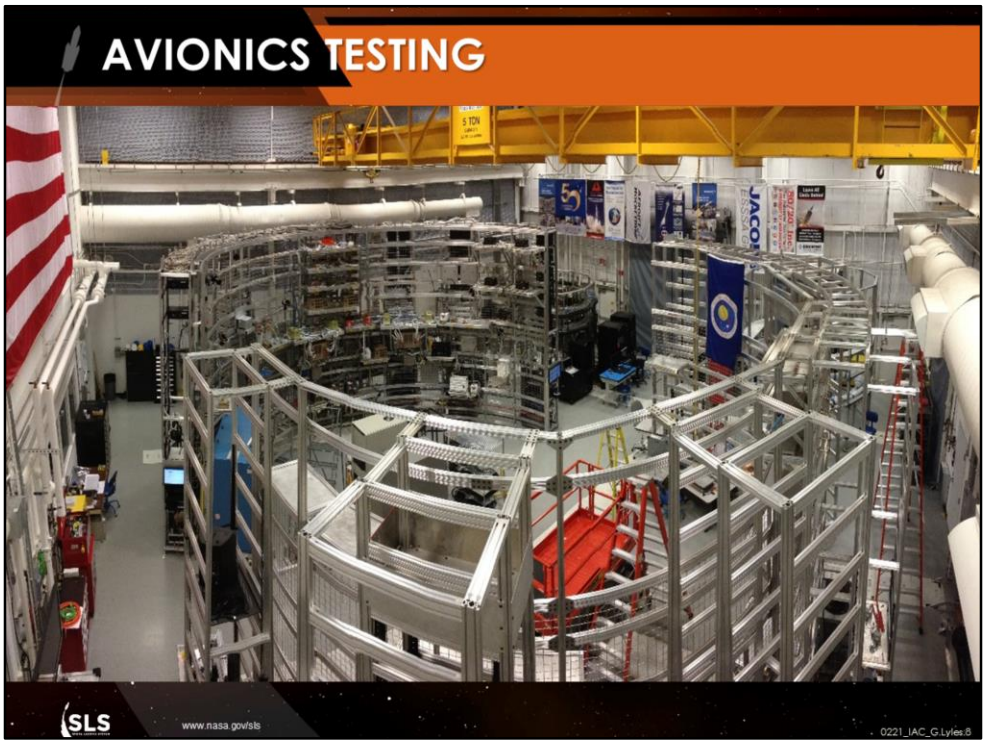


- **Core Stage will be world's largest stage – 212 feet tall and 27.6 feet diameter, 144,000 kg LH2 and 820,000 kg LOX**
- **Manufacturing at NASA Michoud Assembly Facility, Louisiana**
- **Six major manufacturing tools, largest is Vertical Assembly Center, successfully overcame VAC setup issues**
- **Completed to date: engine section, LH2, and LOX weld confidence articles; engine section and LH2 qualification articles; work under way on LH2 flight article**
- **Plan to complete all primary structural welding on remaining STAs and flight articles in calendar 2016.**

VIDEO: time lapse video of LH2 qual tank - 27.6 seconds

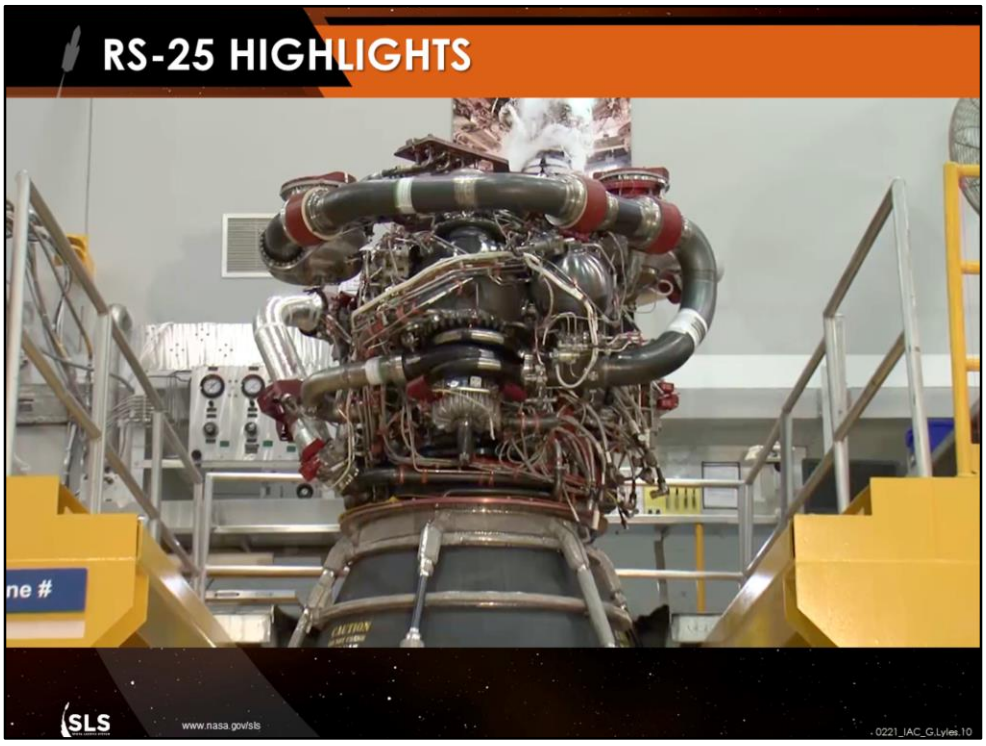


- **Construction underway on LH2 and LOX structural test stands at MSFC – also engine section, intertank, and Integrated Spacecraft and Payload Element STAs.**
- **Work continuing in 2016.**



- **Core Stage/vehicle avionics developed in-house at MSFC**
- **Integrated Avionics Test Facility at MSFC supports development and testing of flight software, also integration of booster, engine, Orion, and GSDO software/emulators**
- **Conversion from SITF-D to SITF-Q in 2016**

- **16 heritage flight engines – used as expendable – plus 2 development**
- **Extensive experience**
- **Proven performance**
- **Adaptation testing of RS-25 to SLS performance requirements – higher inlet pressure, lower inlet temperatures**
- **Addition of new controllers and nozzle insulation**
- **As of August 1, SLS conducted a total of 11 development engine tests totaling more than 4,500 seconds of hotfire time, including EM-2 engine 2059.**
- **Upcoming development engine and EM-2 engine hotfire testing, including new flight ECUs**
- **Developing post-EM-4 new-build engines optimized for affordability**
- **Incorporate additive manufacturing**



VIDEO: Engine assembly and first EM-2 engine test – 24.58 seconds

- **Proven performance from Shuttle and Ares programs**
- **New avionics, improved nozzle layup, relocated aft attachment point, beefed up forward attach point, deleted recovery features**
- **Completed cold- and hot-temperature booster qualification tests in 2015 and 2016 at OATK in Utah**
- **Casting underway on EM-1 flight motors**
- **Overcame processing issues with the 5-segment motor**

VIDEO: Booster manufacturing and QM-2 highlights – 25.73 seconds

Clockwise from upper left:

- **LVSA structural test article completed at MSFC this year**
- **ICPS structural test article completed 2015 at ULA in Decatur, Alabama, delivered to MSFC for testing in 2016**
- **Stennis Space center B2 green run test stand work packages under way**
- **Lengthened Pegasus barge now being outfitted to support transportation to MSFC and KSC**

Other Testing not shown:

- **Base heating**
- **Wind tunnel**

VIDEO: SLS launch sequence – 33.76 seconds

- **This is what we are all working toward, the EM-1 mission now set for late 2018.**
- **Ambitious schedule of manufacturing and testing for the next 2 years.**

- **These are just some highlights. There have been many more.**
- **Best way to follow us is on the various NASA and social media internet sites.**
- **Thanks, glad to take questions.**