Expanding human presence into the solar system starting with the Lunar Gateway

Tracy R. Gill

NASA/Kennedy Space Center

March 8, 2019 – Hagerty High School

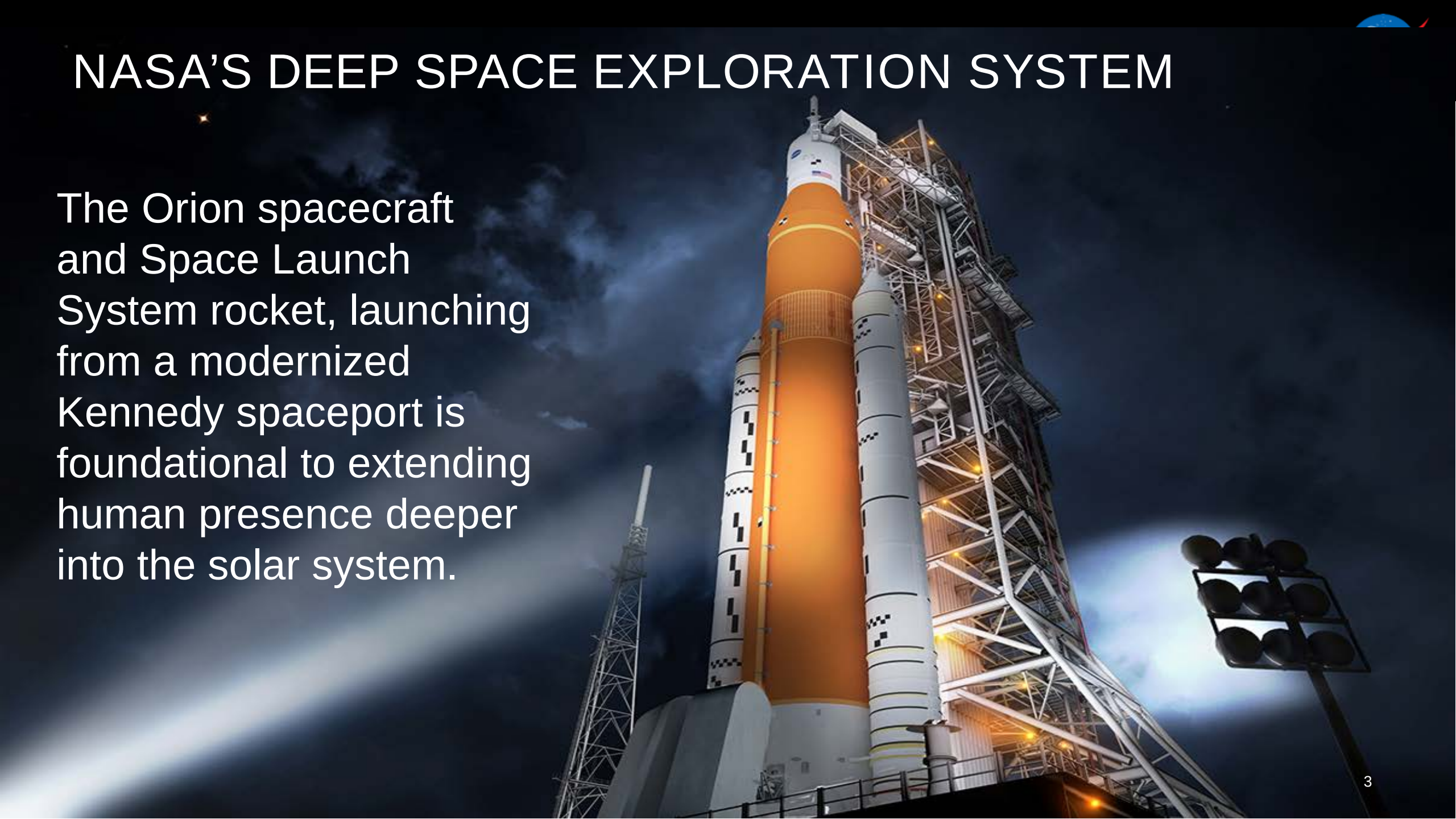
Space Policy Directive-1

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.

Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.”

NASA'S DEEP SPACE EXPLORATION SYSTEM

The Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport is foundational to extending human presence deeper into the solar system.



How do we start and what is it called?

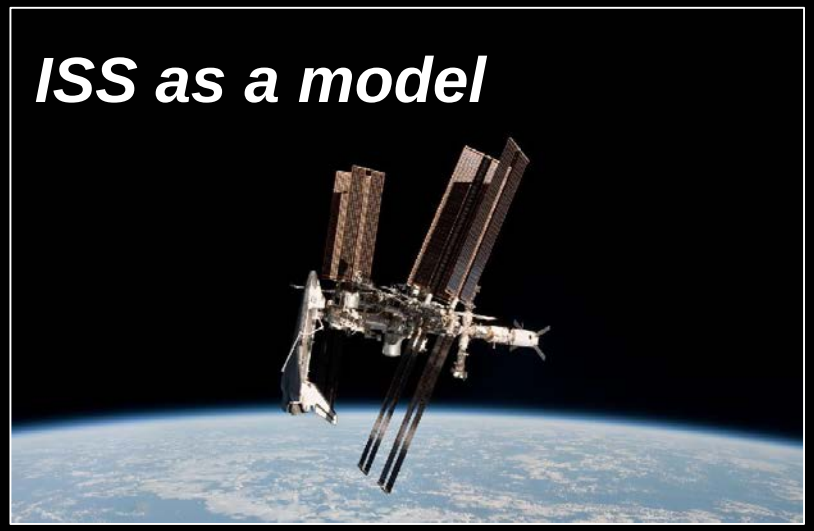
Deep Space Gateway

Lunar Orbital Platform - Gateway

Gateway

NASA'S Open Architecture Develops Space

ISS as a model



Cygnus (Orbital ATK)

Dragon (SpaceX)

Dream Chaser (SNC)

Dragon Crew (SpaceX)

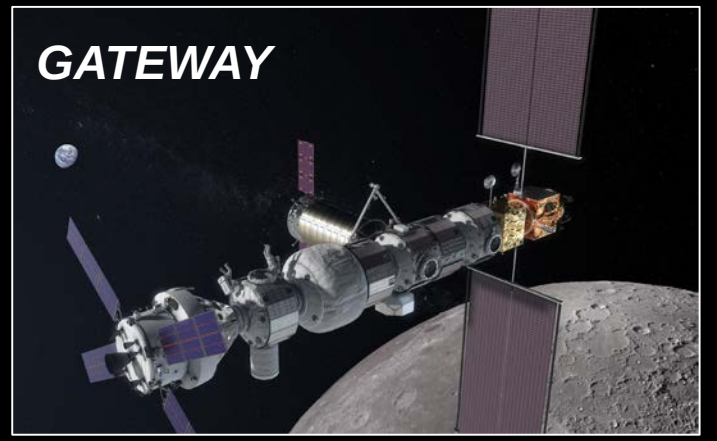
Starliner (Boeing)

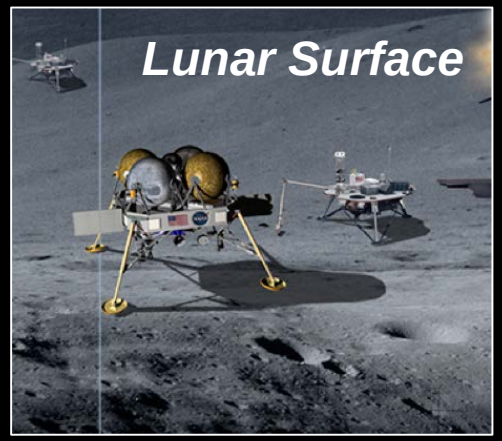
INTERNATIONAL

Soyuz & Progress (Roscosmos)

H-II Transfer Vehicle (JAXA)

Orion/European Service Module (ESA)





Multiple providers expected in lunar orbit and on the surface

NextSTEP Habitation

NextSTEP Phase 1: 2015-2016

Cislunar habitation concepts that leverage commercialization plans for LEO


LOCKHEED MARTIN


BIGELOW AEROSPACE


ORBITAL ATK


BOEING

FOUR SIGNIFICANTLY DIFFERENT CONCEPTS RECEIVED

Partners develop required deliverables, including concept descriptions with concept of operations, NextSTEP Phase 2 proposals, and statements of work.

NextSTEP Phase 2: 2016-2019

- Partners refine concepts and develop ground prototypes.
- NASA leads standards and common interfaces development.


BIGELOW AEROSPACE


BOEING


LOCKHEED MARTIN


SIERRA NEVADA CORPORATION


NORTHROP GRUMMAN


NANORACKS

NASA defines reference habitat architecture in preparation for Phase 3.

Phase 3: 2019+

- Partnership and Acquisition approach, leveraging domestic and international capabilities
- Development of deep space habitation capabilities
- Deliverables: flight unit(s)

Habitation Development Partnerships

Five full-sized ground prototypes will be delivered for testing in 2019. In final negotiations with NanoRacks for sixth habitat prototype demonstrator.

Lockheed Martin
Denver, CO

Refurbishes heritage hardware

Government Evaluation Location: KSC

Northrop Grumman
Dulles, VA

Builds on proven cargo spacecraft development

Government Evaluation Location: JSC

Bigelow Aerospace
Las Vegas, NV

Expandable

Government Evaluation Location: Las Vegas

Boeing
Pasadena, TX

Leverages existing technologies

Government Evaluation Location: MSFC

Sierra Nevada
Louisville, CO

Modular buildup

Government Evaluation Location: JSC

NanoRacks
Louisville, CO

Converted Centaur upper stages

Government Evaluation Location: MSFC

INTERNATIONAL INTEROPERABILITY STANDARDS

Draft Deep Space Interoperability System Standards
Posted for feedback on March 1, 2018

- **Avionics**
- **Communications**
- **Environmental Control and Life Support Systems**
- **Power**
- **Rendezvous**
- **Robotics**
- **Thermal**

www.InternationalDeepSpaceStandards.com

NextSTEP Phase 2 Parameters

- Each contractor has approximately a 2 year window from contract start
- 18 months to
  - Develop deep space architecture and allocate needed functions to modules
  - Design concept habitat and then design and build ground prototype demonstrator emphasizing features of merit using avionics test beds, physical mockups, augmented reality and virtual reality, modeling and simulation tools, and more…
- Contractors determine design process and recommend milestones
- After the 18 month contractor period, the government has up to 6 months to evaluate the architecture

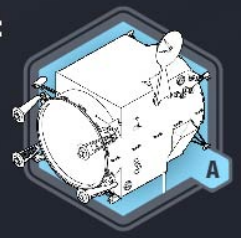
Schedule Complexity

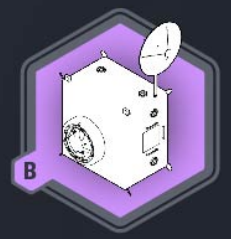
- Each contractor team is working to their own design process
- The various contractor schedules overlap because of the staggered contract starts and include quarterly and review milestones; technical monitor, ground test, and life support system tag-ups; and various other splinter sessions
- Managing just the schedule conflicts much less the associated travel becomes challenging
- NextSTEP added an experienced operations engineer to manage a coordinated schedule across the contractors including both the contractor development phase and ground testing during the NASA evaluation phase
- Schedule coordination first topic of weekly contractor technical monitor meetings

GATEWAY

An exploration and science outpost in orbit around the Moon

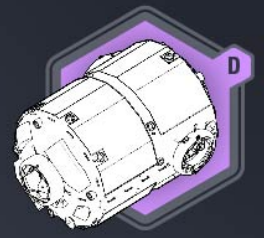
Power and Propulsion Element:
Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.

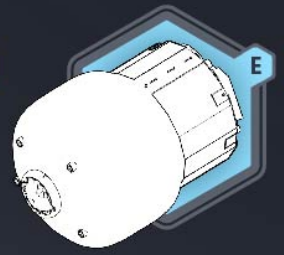




ESPRIT:
Science airlock, additional propellant storage with refueling, and advanced lunar telecommunications capabilities.

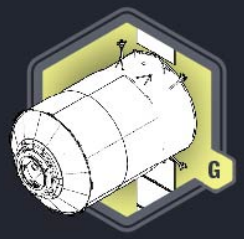
Utilization Element:
Small pressurized volume for additional habitation capability.





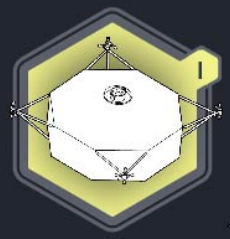
Habitation Modules: Pressurized volumes with environmental control and life support, fire detection and suppression, water storage and distribution.

Robotic Arm:
Mechanical arm to berth and inspect vehicles, install science payloads.

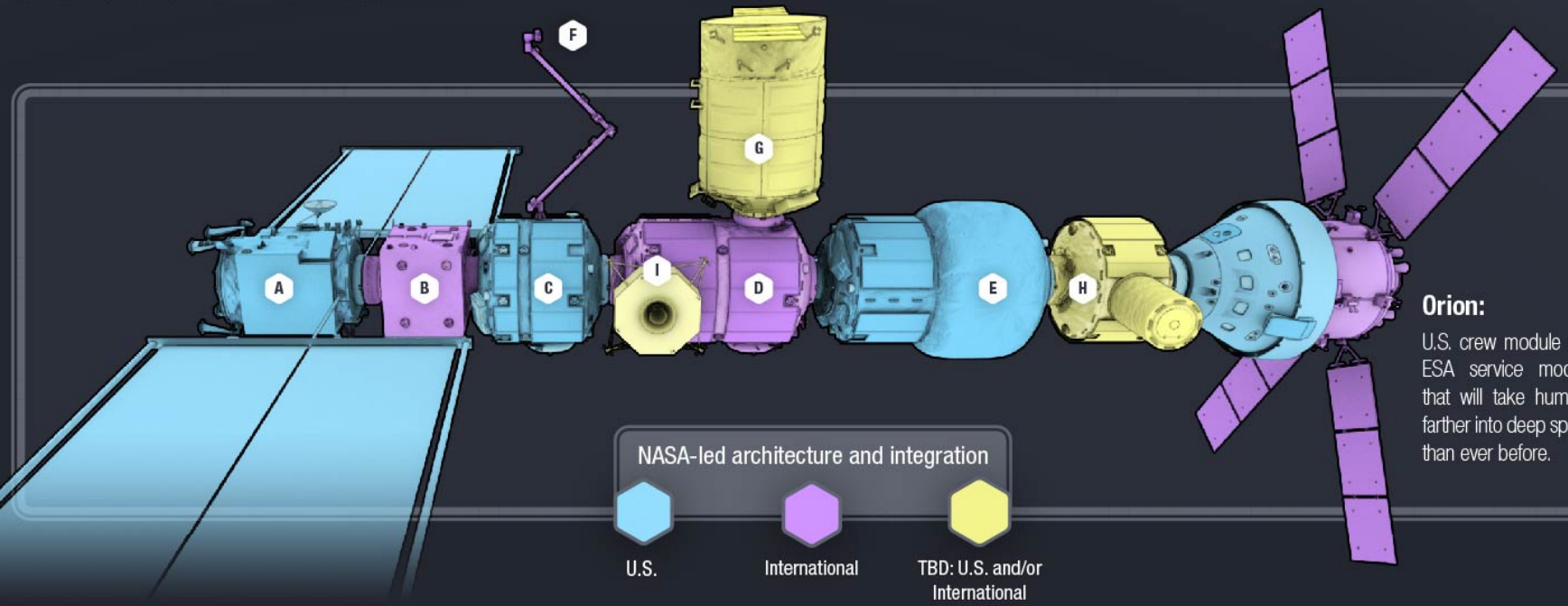


Logistics and Utilization:
Cargo deliveries of consumables and equipment. Modules may double as additional utilization volume.

Airlock:
Enables spacewalks, potential to accommodate docking elements.



Sample Return Vehicle:
A robotic vehicle capable of delivering small samples or payloads from the lunar surface to the Gateway.

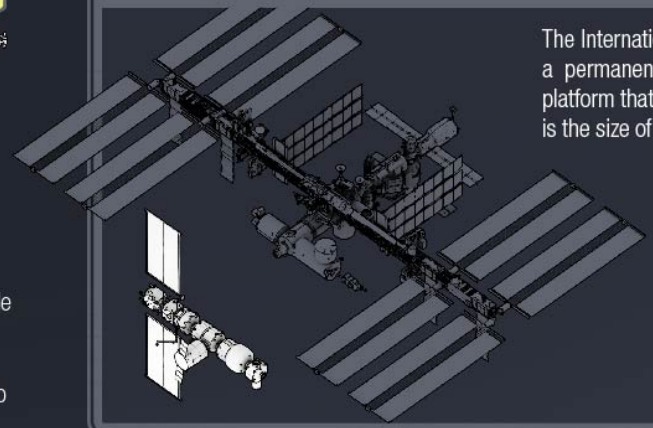


Orion:
U.S. crew module wth ESA service module that will take humans farther into deep space than ever before.

NASA-led architecture and integration

U.S. | International | TBD: U.S. and/or International

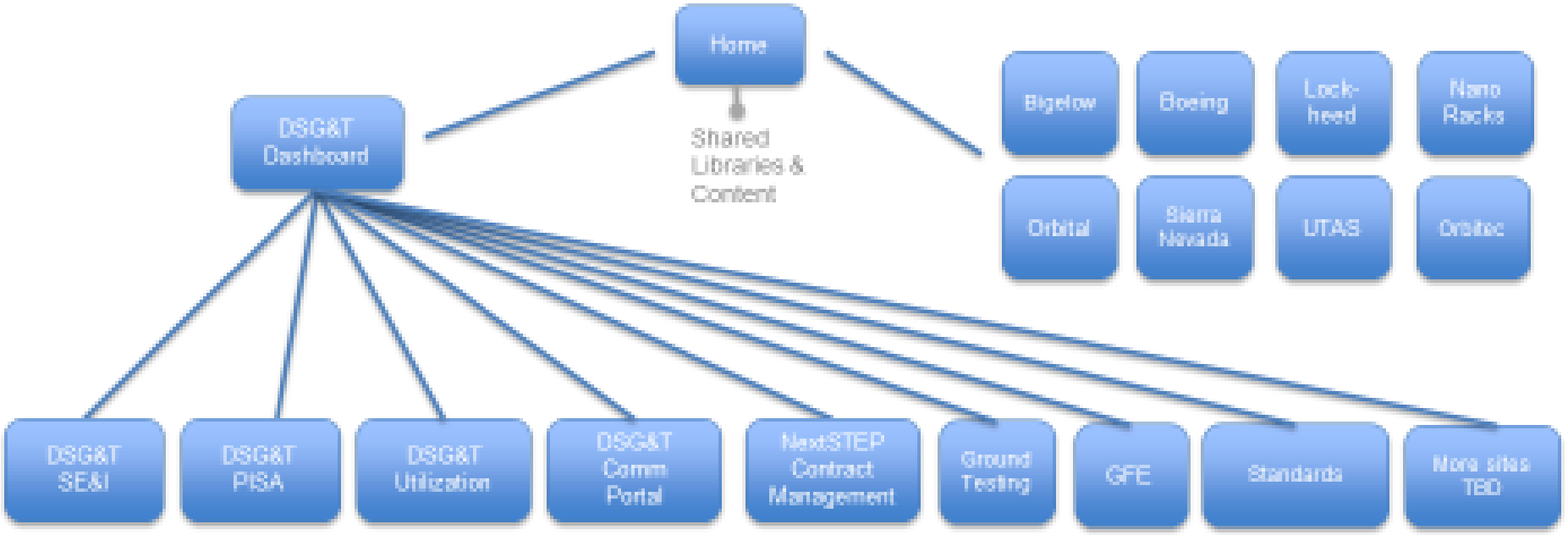
Gateway Compared to the International Space Station



The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

The Gateway is a much smaller, more focused platform for extending initial human activities into the area around the Moon.

SharePoint Architecture



DSG&T SharePoint is the primary means of transmitting information between individual contactors and NASA. Authoritative sources of information and final contract material is maintained in this environment. The primary structure is divided into 3 parts:

- **DSGT Home:** One shared collaboration site for all DSG&T participants
- **Contract Companies:** Each company has a dedicated site for collaborating with their respective Technical Monitor. Requires Contractor POCs to obtain NASA identities and transmit NextSTEP data through SP.
- **DSGT Dashboard:** Each NASA internal team will have a dedicated site for collaborating

- NextSTEP is using collaboration system suite of tools to manage the various work efforts
- There are domains for NASA, contractor, and various combinations of NASA/contractor access
- This chart gives some insight into the complexity of the activities within NextSTEP Habitat Phase 2 effort

Challenges

- Doing hard things, the unknown, pushing exploration
- Intellectual Property
- Export Control – how we protect sensitive technical information from foreign intelligence
- Distributed teams – across the country and the world
- Limited Resources and time

Tools – how do we do the work we do

Examples of some of the tools we use in our daily work

- Virtual teams across the United States and the world
  - Travel, Video Conference (e.g. Vidyo), Teleconference, Desktop Sharing (e.g WebEx, Skype)
- Microsoft SharePoint for collaboration, documentation, archiving, schedule integration, status
- Productivity Tools – Outlook with secure features, PowerPoint, Excel, Word
- Modeling and Simulation using Maya, MATLAB, Simulink, etc.
- Design tools – Pro-E, AutoCAD
- Secure cell phones

Solving Problems and Getting Results

- Approach
  - Build, test, learn is usually the fastest way to make progress rather than overanalyzing – 3D printing, machine shops, prototyping labs, analog tests
- Resources
  - Budget – you never have as much as you want. Drives innovation
  - Information - Archives, Lessons Learned, Internet tools
  - Collaborators - People are the best resource. People are everywhere and you need their help to succeed! You can't do much of anything without a team.
  - Partners - schools, universities, companies small and large.
- Recording lessons, findings
  - Technology Transfer - https://technology.nasa.gov/
  - NASA Technical Report Server - https://www.sti.nasa.gov/

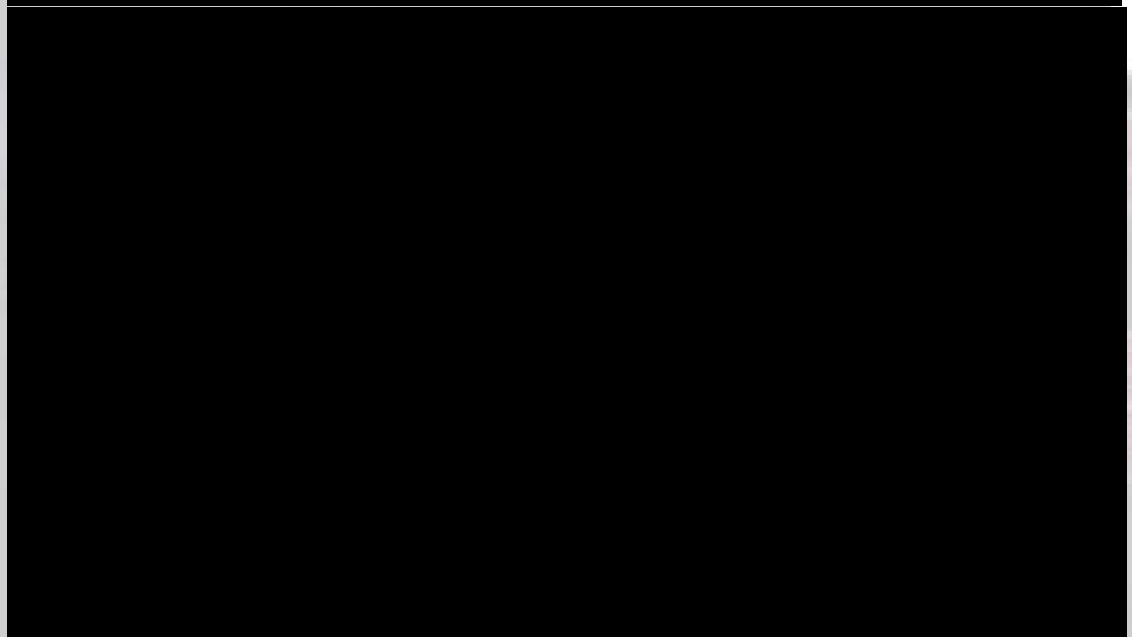
Lockheed NextSTEP Habitat Media Info

- How AR And VR Could Help Get Humans To Mars -
- Lockheed Martin gives first look into where astronauts may live on missions to deep space
- Lockheed Martin offers glimpse into its lunar habitat modules
- Astronauts could stay at this space 'motel' on the way to Mars
- Astroanuts Could Soon be Living in a Deep Space RV
- Lockheed NextSTEP Lunar Habitat Flickr account

NextSTEP Habitat Concept Assembly video

- Lockheed Gateway Assembly

- Sierra Nevada Corporation video
- Boeing Gateway assembly video



- NGIS Gateway assembly video

Value of the NextSTEP Phase 2 Contracts

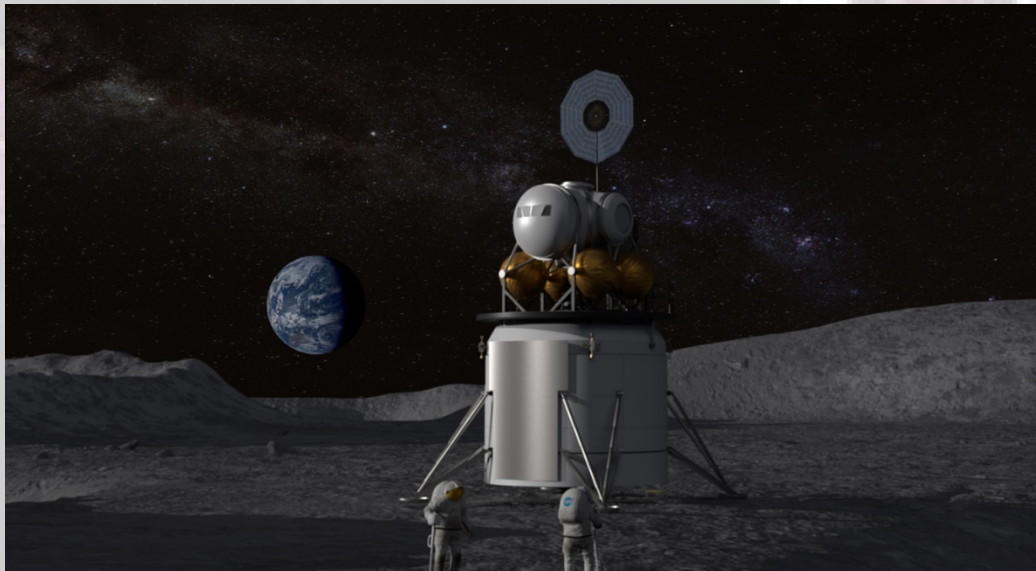
- First NextSTEP Phase 2 work has informed NASA of diverse architecture and concept of operations approaches and afford an opportunity to assess those approaches.
- Next, these contracts have provided options for acquisition strategies because the Phase 2 work was competitively awarded.
- The Phase 2 work has resulted in better standards and interfaces because of the collaborative efforts across the contractors as well as the public input.
- It also helped inform and confirm NASA trades during NASA requirements development.
- The work is expected to contributed to developing realistic cost and schedule targets for Gateway, and it has enabled testing of different habitat and integration concepts.
- And finally, the Phase 2 contract work has enhanced the experience base both in NASA and contractors in design, development, and testing of space habitat systems.

Coming soon….

- Stay tuned for results and new developments
- Phase 2 prototype testing in 2019
- Procurement to begin for first Gateway element (Power and Propulsion Element) starting late 2018
- And lunar landers…

Human Lunar Landers

- On February 7, 2019, NASA announced the next set of public private partnerships for lander systems that will enable a return to the moon using government systems like SLS, Orion, and the Gateway and commercial launch and cargo services
  - https://www.nasa.gov/feature/nasa-seeks-us-partners-to-develop-reusable-systems-to-land-astronauts-on-moon



Moon Hoax? – No way!

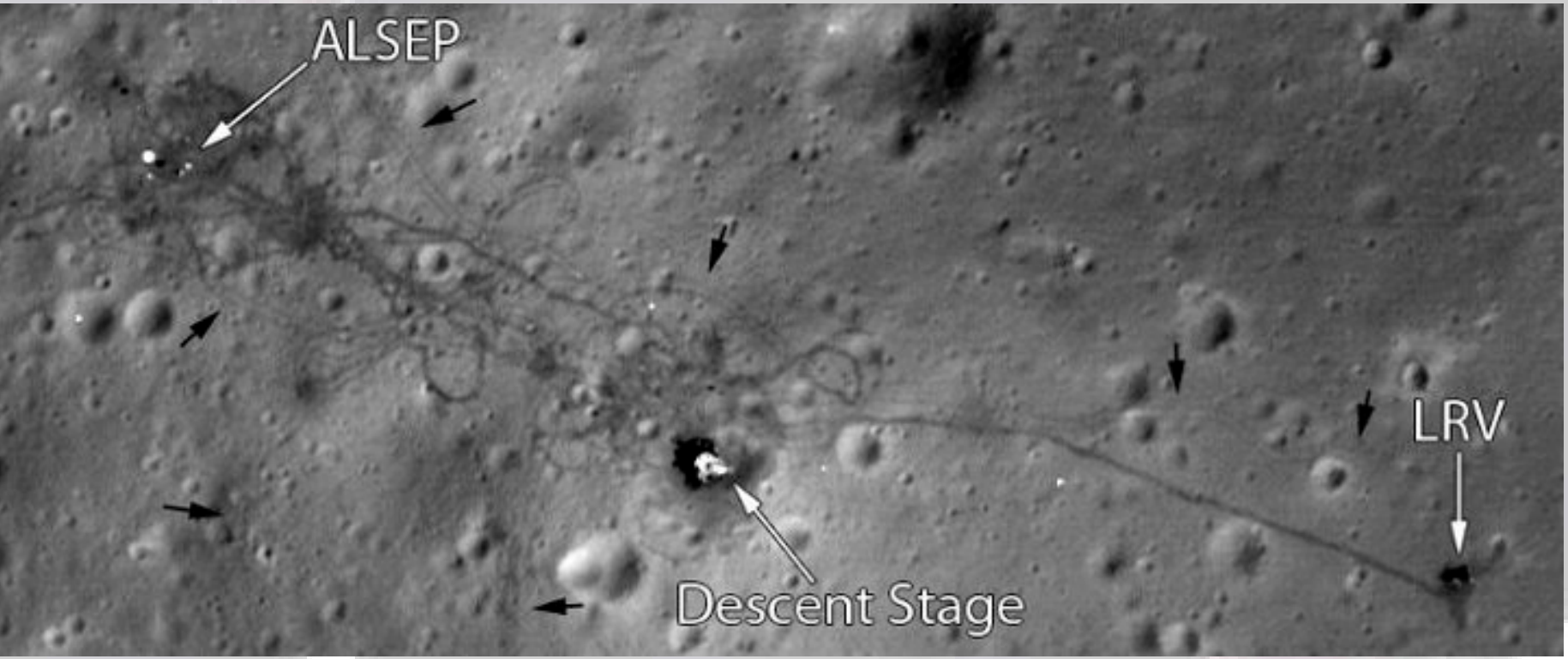


Image of the Apollo 15 landing site from the Lunar Reconnaissance Orbiter

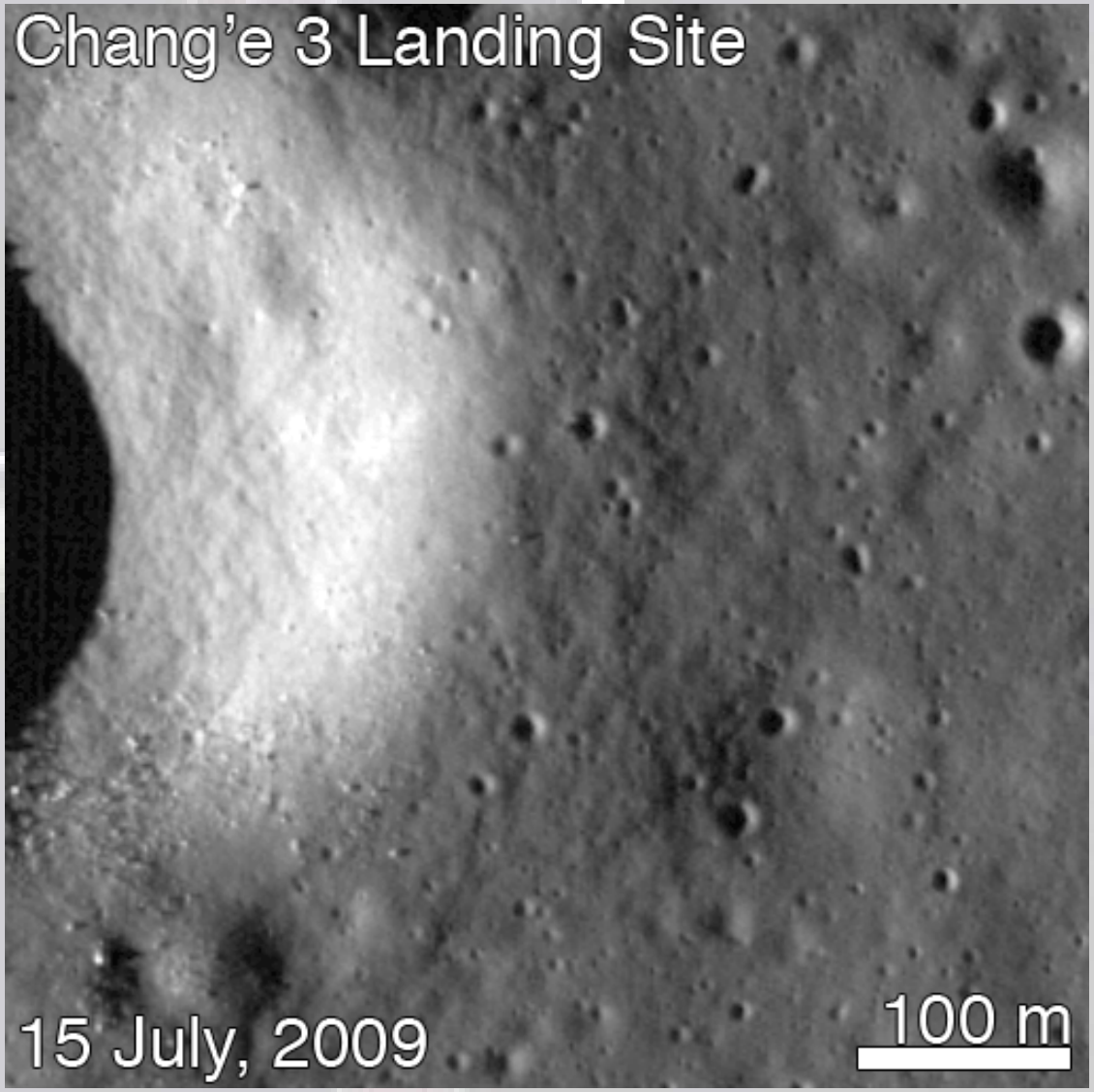
Apollo 15 image from the lunar surface

Other interesting tidbits

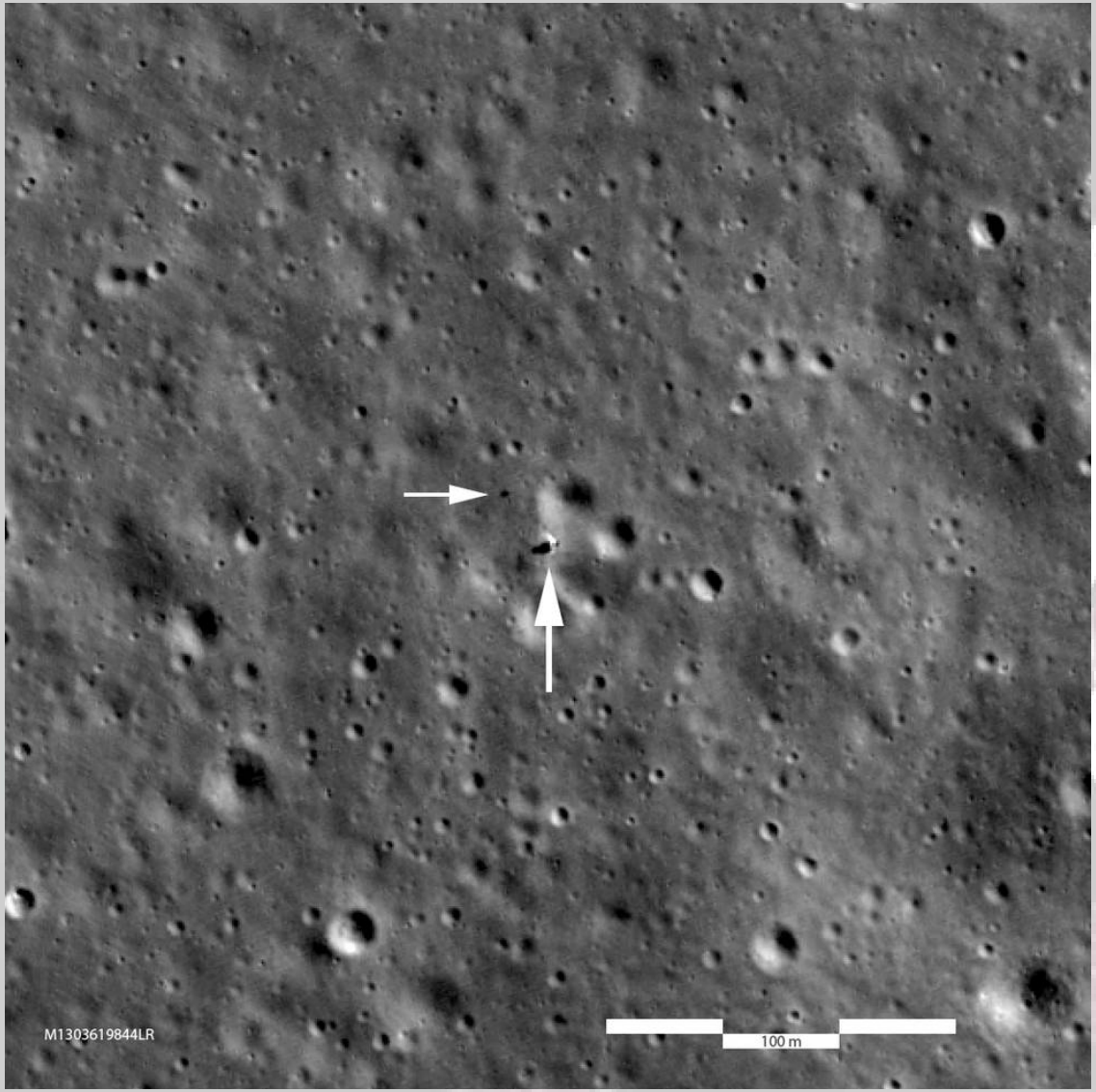
- NASA Tournament Lab - Challenges and opportunities for the public to solve problems and analyze data
- NASA 3D objects - You can make 3d prints of NASA systems or use them in modeling software tools

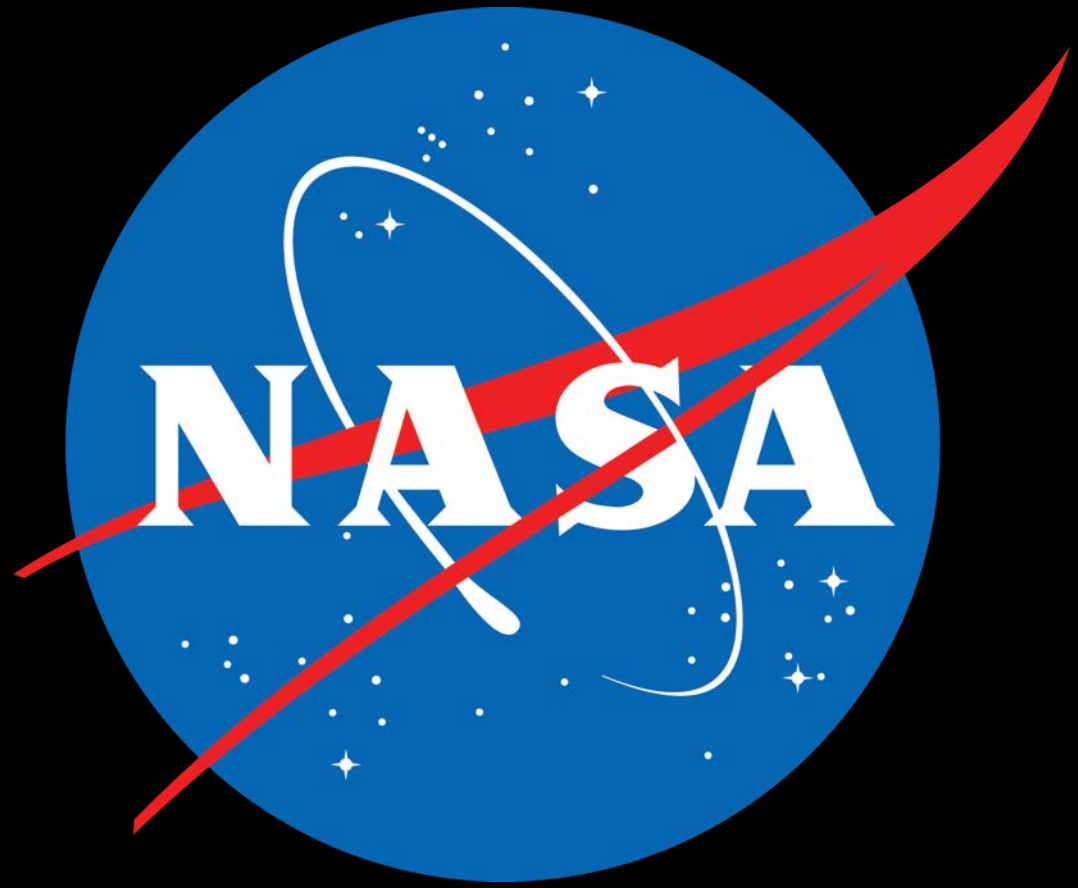
These are public images from the NASA Lunar Reconnaissance Orbiter of the last two Chinese lunar landers

- LRO – Chang'e 3 image
- LRO – Chang'e 4 image



Chang'e 4 – Feb 1, 2019





Questions?

References

- *A Novel Approach in Public-Private Partnership Execution with NextSTEP-2 Habitat Systems*, AIAA Space 2018, T Gill (2018)
- *Playing Nice Across Time and Space*, M. Conroy and R. Mazzone (2015) https://ntrs.nasa.gov/search.jsp?R=20150019921&hterms=conroy+habitat+demonstration+unit&qs=N%3D0%26Ntk%3DAll%7CAll%26Ntx%3Dmode%2Bmatchallany%7Cmode%2520matchall%26Ntt%3Dhabitat%2Bdemonstration%2Bunit%7Cconroy

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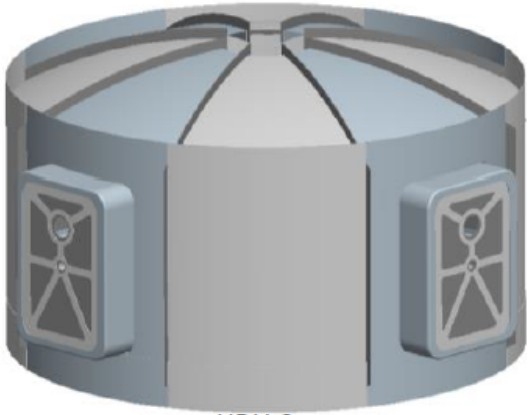
Concurrent Design Observation

Habitat Demonstration Unit

HDU Overview

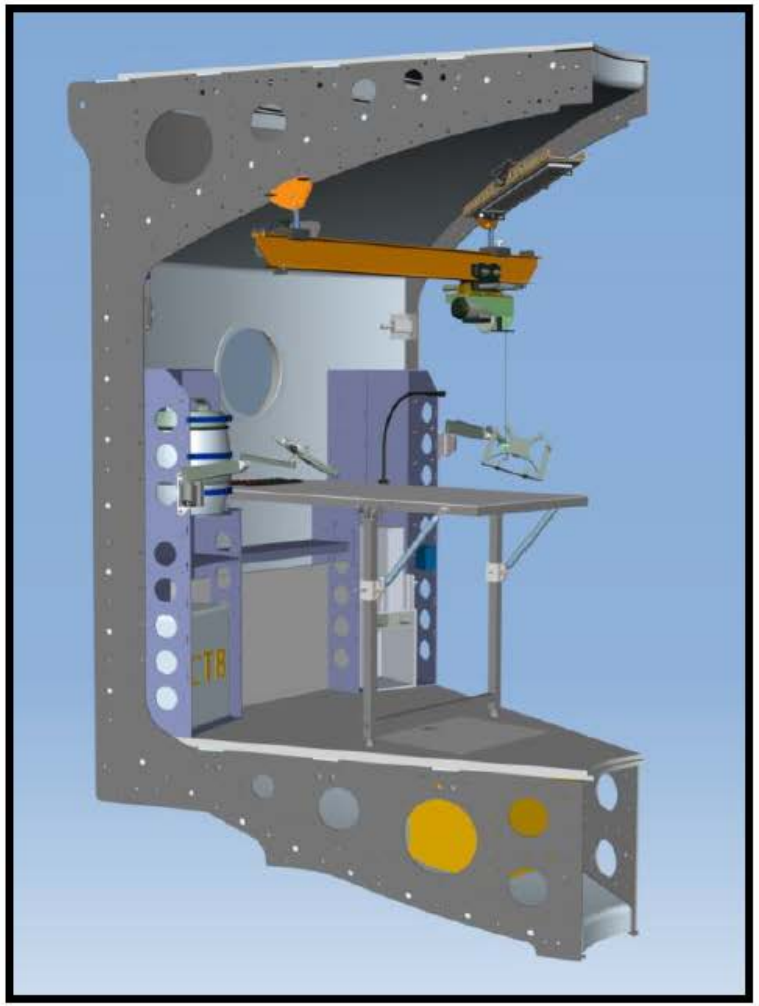
- Vision
  - Develop, integrate, test, and evaluate a Habitation prototype to better understand mission architectures, requirements and operational concepts
- Timeline
  - Project Kick-off: **June 2009**
  - Shell: October 2009 – April 2010
  - Systems Integration: **April – August 2010**
    - 10 Month Build, 4 Month Integration
  - Field Test at Desert RATS September 2010
- Participation
  - Jointly managed and built across 3 Time Zones with subsystems from 7 Centers

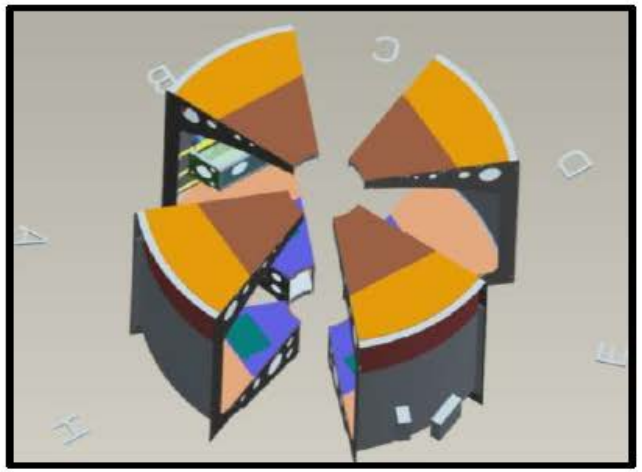
Lunar Reference Concept (PEM)

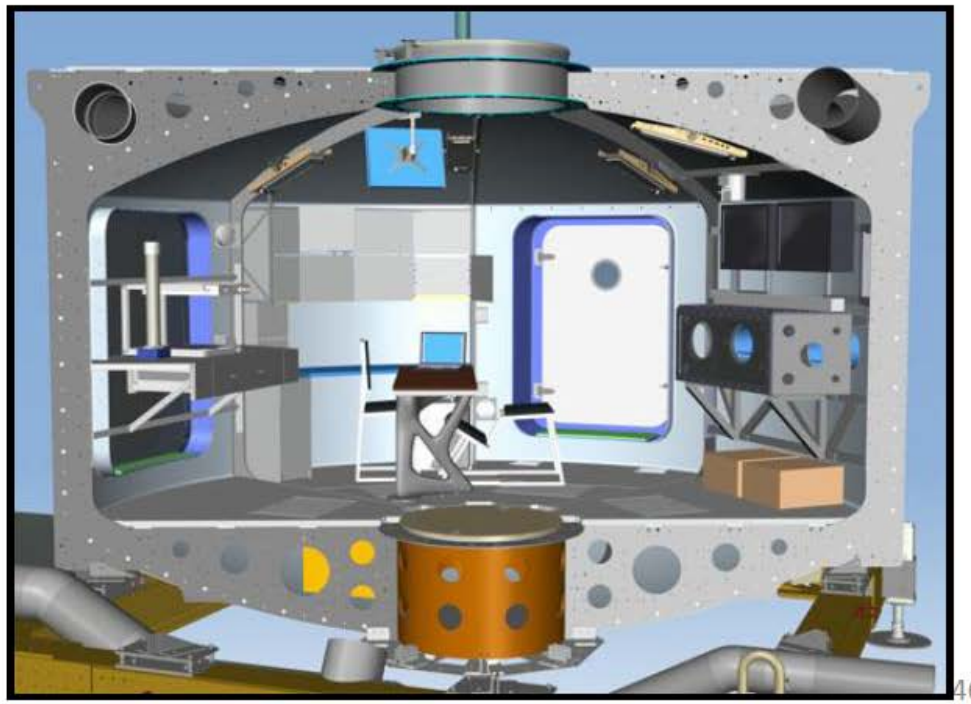


HDU Concept

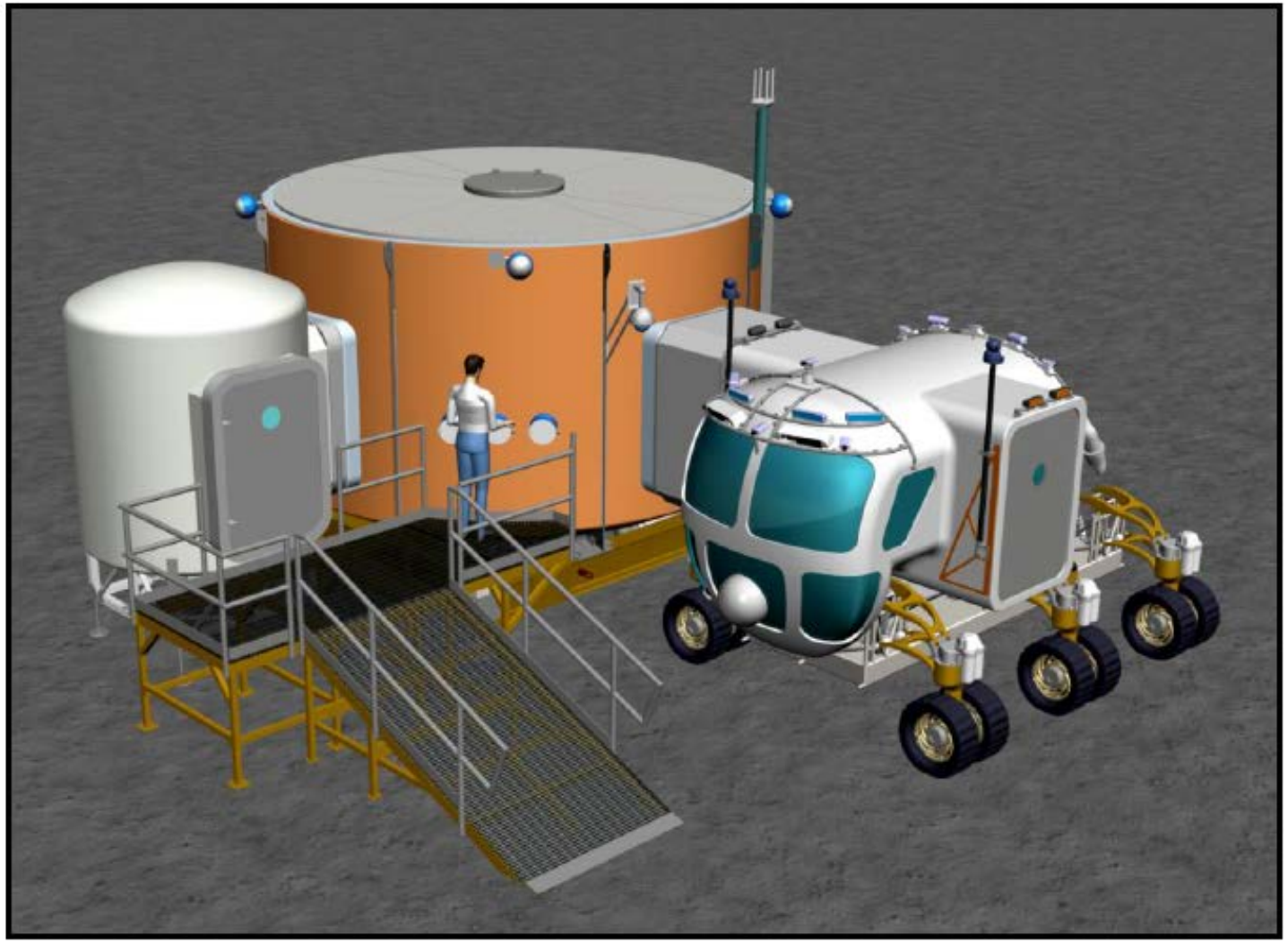
CAD Based Integration - Interior



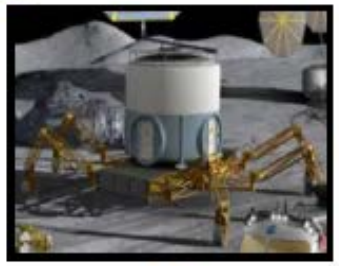


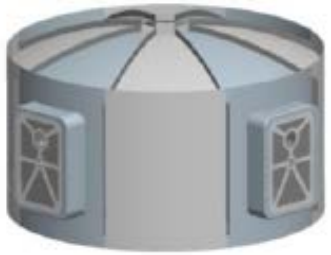


CAD Based Integration - Exterior



Concept Realization (15 Months to Field)





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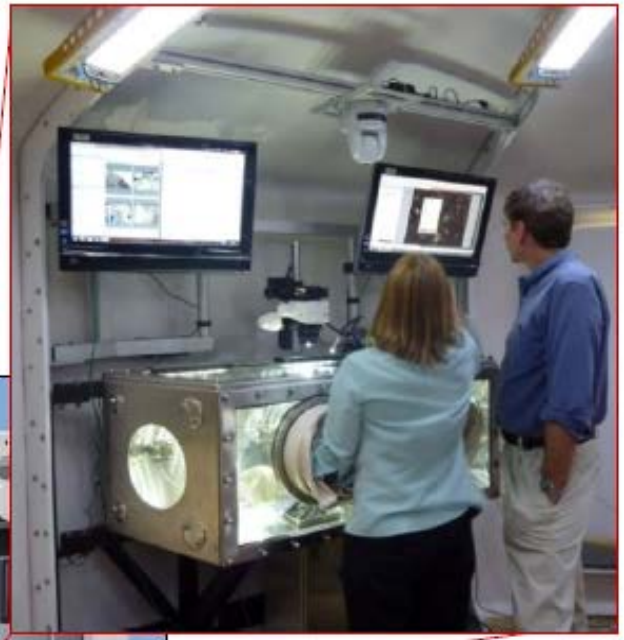

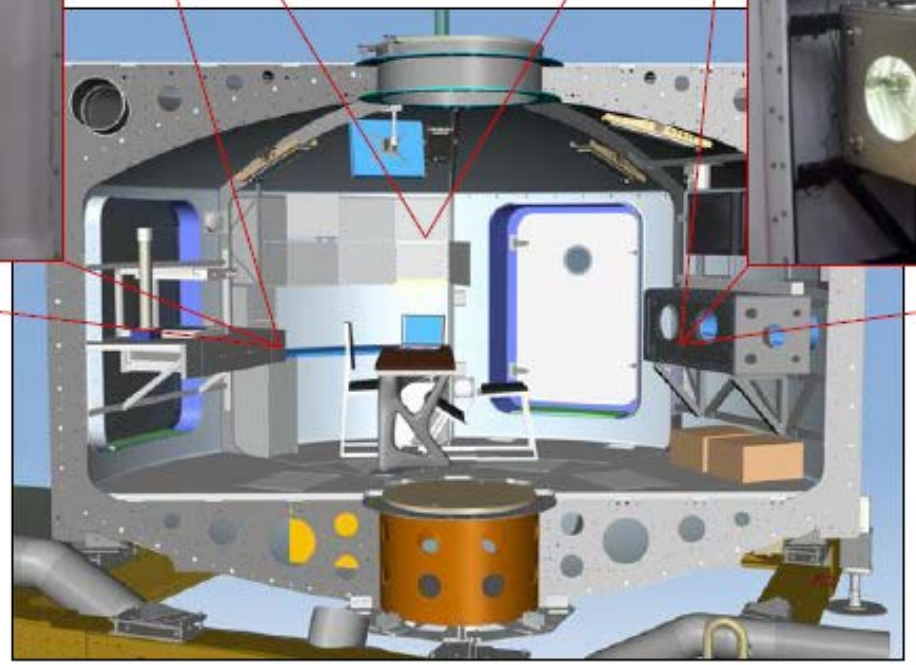

Concurrent Design Lessons

- CAD integration rapidly grew to system simulation, then concurrent development
  - Concepts were matured in design sessions
    - Concept developed, "model" updated, package base lined
    - Design completed, "model" updated, systems built
    - Multiple Centers, Teams, Projects, Time Zones and Budgets
- **Success not just because of Simulation**
  - **HDU leadership prioritized decisions such that time critical elements were decided on first**
    - **Even if only allocations**
  - **Simulation Screen Shots became a key communication path**
    - **Timely, Enhanced Understanding, Converged Ideas**

Intellectual Property (IP)

- Developed a program specific best practices guide for handling sensitive information, additional engagement with data IP attorneys
- Incorporating additional training on IP and data rights for personnel engaging with the contractors
- Implemented custom IP clauses in the contracts
- To protect sensitive information, the NextSTEP contracts include the standard Federal Acquisition and NASA regulations that require marking the data as “Limited Rights Data/Information in Accordance with FAR 52.227-14 as Modified by NFS 1852.227-14.”
- Civil servants are bound by the United States Trade Secrets Act, which requires that civil servants protect proprietary information they receive in their official capacity and carries criminal sanctions.