

# Lockheed Martin

## *Engineering a Better Tomorrow*

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Elton Witt

Lockheed Martin Fellows

Human Health and Performance







## Extracting Secrets from an Asteroid

NASA's OSIRIS-REx mission aims to visit the small asteroid named Bennu and collect and return a sample of regolith - which holds information on the composition and the processes that have shaped the object's evolution. Why? To give us the greatest clues yet into how life originated here on Earth. Learn how one small object tested in the mountains of Colorado will help make it happen.



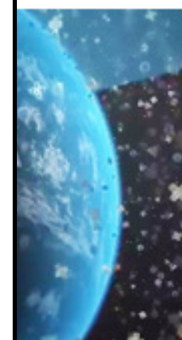
## Insight to Uncover the Secrets of Planets

Exploration missions are helping us gain a better understanding about what it may take for humans to explore Mars. InSight will be the first mission to make measurements of Mars' interior. It will provide the greatest clues yet into the processes that shaped the inner solar system.



## Brain-Powered Machine Learning

Reports show the number of concussions continues to grow in amateur and professional sports. In response, Lockheed Martin neuroscience engineer Bill Rose and a small team of researchers have been studying how to apply machine learning algorithms to brain images from fMRI scans.



## Space Debris

Space debris has become a major concern for space missions. The number of objects in orbit is growing rapidly, and the risk of collisions is increasing. Lockheed Martin is developing advanced systems to track and classify hundreds of thousands of pieces of space debris.

advanced systems to track and classify hundreds of thousands of pieces of space debris.

Railroad – for delivery of supplies in space. One that enables human exploration to destinations deeper in space than ever before.



# Lockheed Martin Corporation

## Culture of Innovation

- 50 years of human space-flight experience with expertise in space-flight hardware development, mission and project management, mission operations, space human factors, space food technology, and space radiation operations
- Deep experience creating advanced information systems as the U.S. Government's Number One IT provider; advanced data analytics capability that offers a variety of actionable data solutions to drive business and health care decisions



# A Legacy of Innovation



What's Next...?

Lockheed Martin NEXT Team

Developing technology and leaders  
to continue our legacy of innovation



# LM's *NEXT* Team: What do we do...

**Ideation**

**Evaluation**

**Execution**

“Attack biggest risks first in order to recognize failure as early as possible”

- Idea source agnostic
- Flexibility to work on ideas we identify
- Multidisciplinary team
- Able to leverage corporation-wide resources
- Think and work outside of the box



# Lighthouse - Center for Innovation

- 50,000-square-foot, high-end laboratory in Suffolk Virginia - part of Lockheed Martin's investment in research and development programs and infrastructure.
- Purpose: collaborative experimentation and analysis: test ideas and analyze concepts to co-create innovative solutions for an ever widening range of customer challenges.
- Used to facilitate numerous Cooperative Research and Development Agreements (CRADA), as well as human in the loop (HITL) experiments and analytical efforts, between Lockheed Martin, its U.S. government, international, academic and industry partners.
- Staffed by trained specialists in operations analysis, modeling and simulation, visualization, and operational domains





# Customers



- Departments of
  - Defense
  - Homeland Security
  - Commerce
  - Energy
  - Health & Human Services
  - Housing & Urban Development
  - Justice
  - State
  - Transportation
- NASA
- Social Security Administration
- Environmental Protection Agency
- U.S. Postal Service
- Intelligence Communities
- 70 other Governments Worldwide



# Our Value is our People

- Over 112,000 employees
- Over 60,000 technical employees
- Corporate Knowledge is one of LM's greatest assets
- Many mechanisms for corporate reachback
  - Engineering Storefront
  - LM Fellows Portal – top engineers who act as expert resources across the corporation
  - Over 200 eForums and Communities of Practice –
    - Put the power of community collaboration to work for you – get answers, learn from others
  - Social Media: Eureka Streams® – social communication platform built to help individuals communicate with one another
  - Brainstorm – problem solving through published challenges
- LM is the #1 rated IT Company in US for 21 years running
- 100+ years in aeronautics!



# Business Structure

## Aeronautics



## Information Systems & Global Solutions



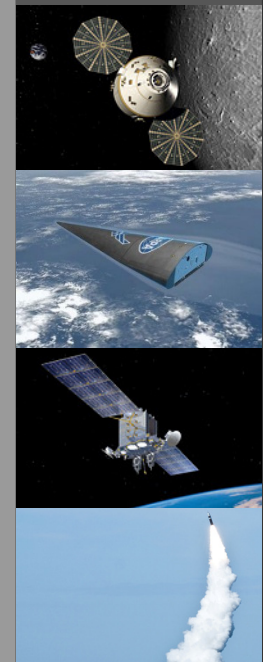
## Missiles and Fire Control



## Mission Systems & Training



## Space Systems



## International





# Space Systems Company (SSC) Portfolio

## Strategic & Missile Defense



Adv Programs



Strategic Missiles



Missile Defense

## Civil Space



NASA Human  
Exploration



Planetary  
Exploration



Weather &  
Environment

## Military Space



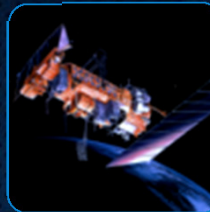
Protected  
Comms



Narrowband  
Comms



Navigation



Weather



Early  
Warning



Space  
Protection

## Special Programs



## Commercial Space



Remote  
Sensing



Commercial  
SATCOM

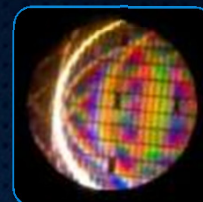


Wind Energy  
Management

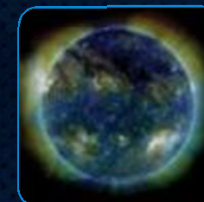
## Advanced Technology Center



Optics, RF  
& Photonics



Adv. Materials  
& Nano Systems

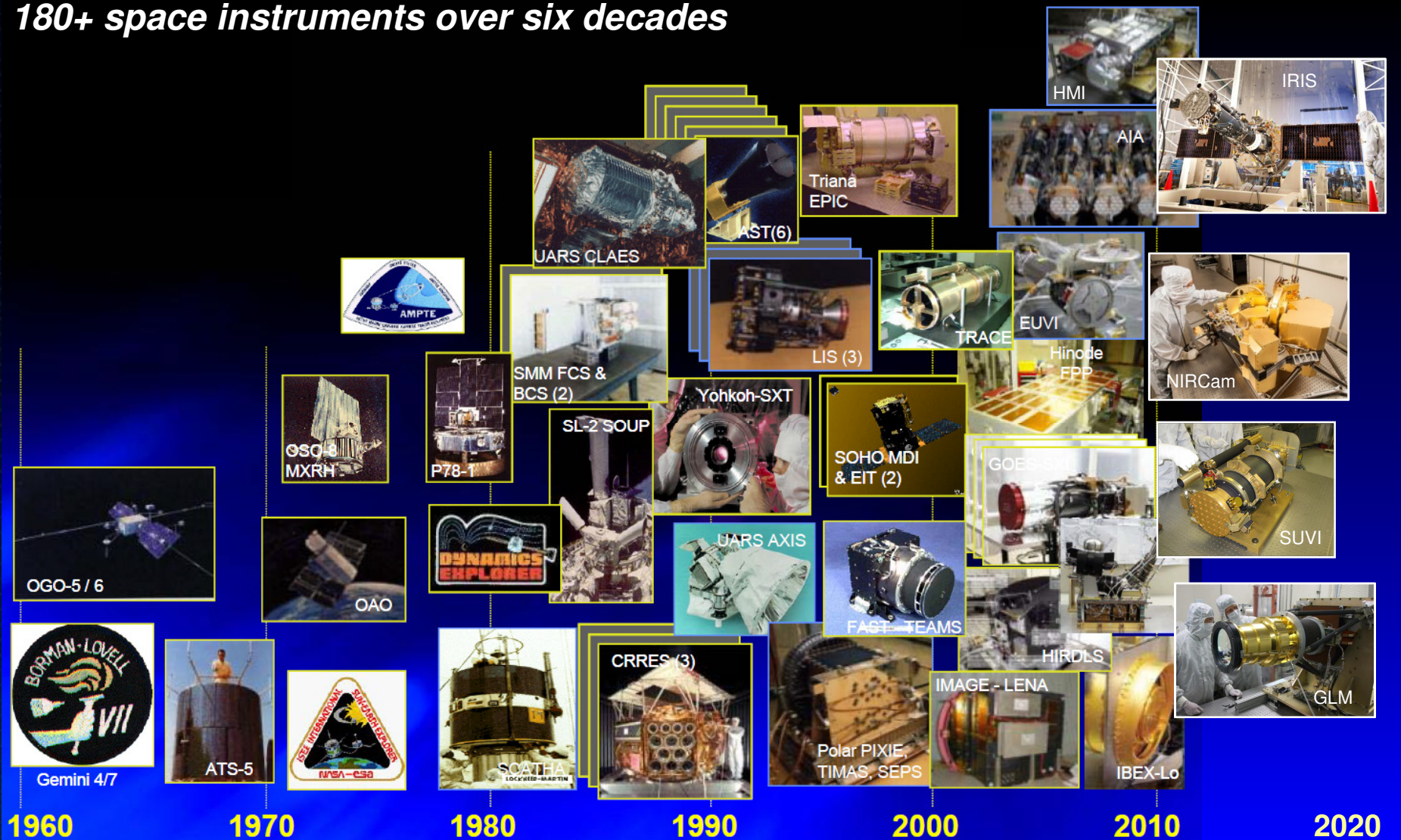


Space  
Sciences &  
Instruments



# Proven Record in Earth Observations, Payloads & Instruments

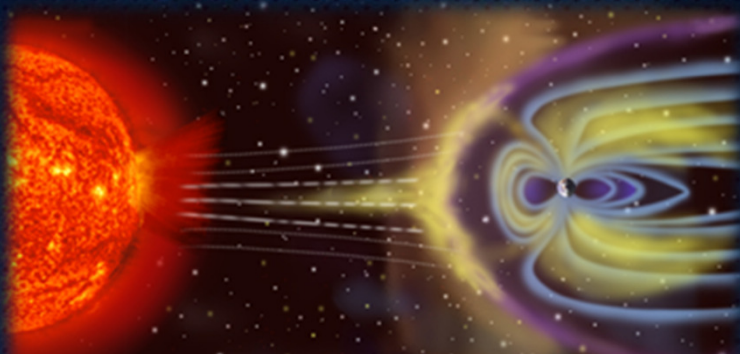
*180+ space instruments over six decades*





# Advanced Technology Center (ATC)

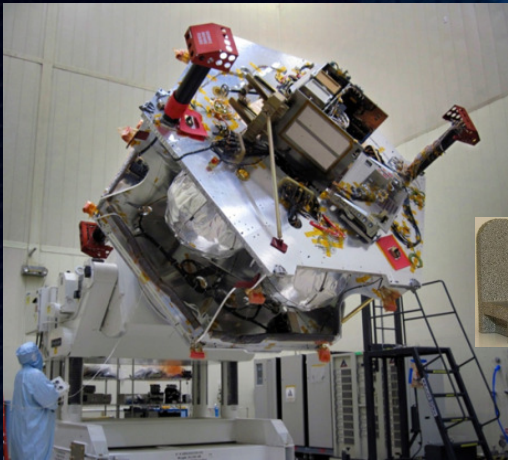
- SSC's R&D Laboratory; ~500 Scientists and Technologist – 2/3<sup>rd</sup> with Advanced Degrees
- Technology Invention & Innovation
- Contracted and Independent R&D
- Payloads and Payload Technologies
- Space and Earth Science
- Classified Advanced Development
- Key Partnerships: Engineering, Universities, and Other R&D Institutions



*Creating the Generation After Next*



# SSC Advanced Materials & Manufacturing



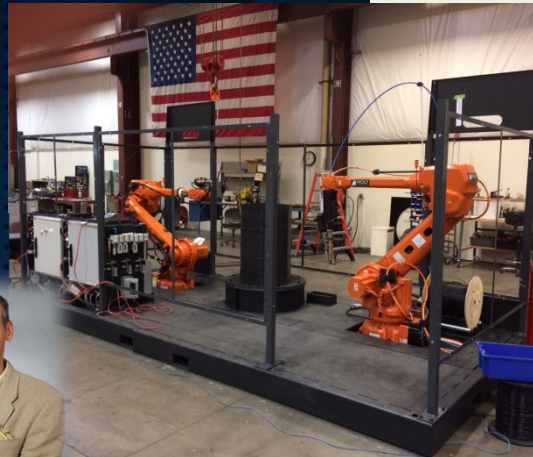
**Selected Juno secondary structures** built using additive manufacturing and CNT-based material



**APEX thermoplastic nanocomposite** comparable strength to 6061 aluminum at lower density and cost



**Titanium propellant tank:** Additive manufacturing for schedule and cost reduction from machining forged billets



**Multi-robot Additive Cluster:** Additive, subtractive, fiber placement, pick and place, monitoring and inspection



*Printing a Satellite through Materials and Manufacturing Innovation*



# Skunk Works®

WE'RE ENGINEERING A BETTER TOMORROW

LOCKHEED MARTIN  
**SKUNK WORKS®**

Innovation with Purpose

For more than 70 years, the Skunk Works has existed to create revolutionary aircraft and technologies that push the boundaries of what is possible. Our unique culture is the key to our success – the secret ingredient that will define the solutions for the next 70 years and beyond.



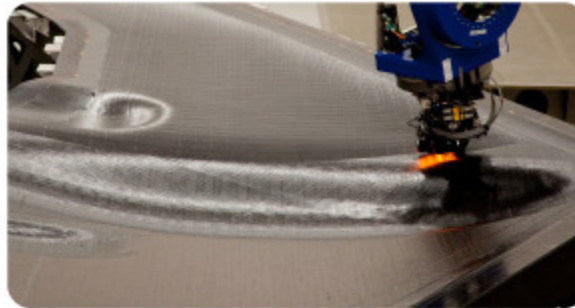


# LM Skunk Works®

## Defining the Future of Aerospace



Air Dominance



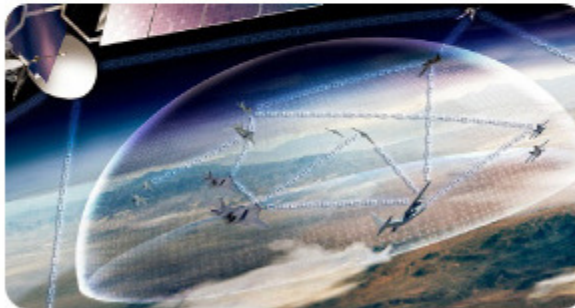
Advanced Manufacturing



High Speed



Air Mobility



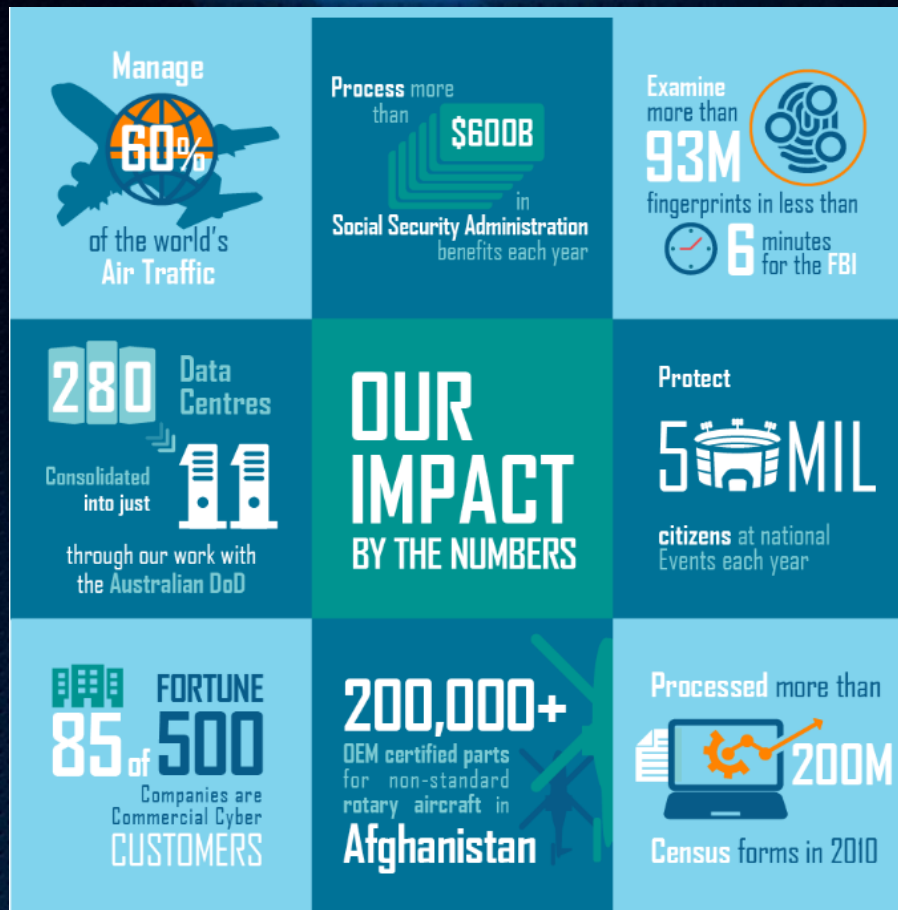
Open System Architecture



Persistent ISR



# Information Systems & Global Solutions (IS&GS)



- ## Focus Areas
- IT Modernization
  - Biometrics
  - Cybersecurity
  - Cloud Computing
  - Health
  - Data Analytics
  - Air Traffic Control

**The majority of LM support to NASA JSC comes from IS&GS**



# NASA New Technology Releases by LM Authors (over 40 in the last 5 years)

- OrionSim-SLSGateWay software
- Interface Anywhere: Gesture and Voice
- Fine Motor Skills Software
- Positional Login (POSLOGIN)
- Information Sharing Protocol Logger
- Micrometeoroid and Orbital Debris Risk Assessment Tool
- Modular Connector Keying Concept
- Non-Powered Spectrophotometry for Lighting
- Joint Execution package Development and Integration (JEDI) Application
- Packaged Food Mass Reduction Technology
- ISS Robotics Planning System (RPS)
- Guidelines for Meal Replacement Bars in a Space Food System
- Two Stage CM-SM Umbilical Mechanism
- Speech Recognition Interface - EMU
- Additive Manufacturing of Nuclear Fuel Pellets
- Cable Retention and Payout Device
- Automated Robotics Mission Designer (ARMD) Software
- Cursor Control Device Test Battery
- Micrometeoroid and Orbital Debris Risk Assessment Code
- Birdstrike UAV
- Flight Dynamics Software (FDS)
- Wearable Sensor Garment Architecture
- Spacecraft Optimization Layout and Volume (SOLV) Model
- Three Degree-of-Freedom Structural Simulator
- Amplification of Vibration Table
- Space Shuttle Ascent/Entry Trainer
- Space Habitability Observation Reporting Tool (iSHORT)
- DNS GUI Software
- Datacenter & network configuration tracking with Visio macros





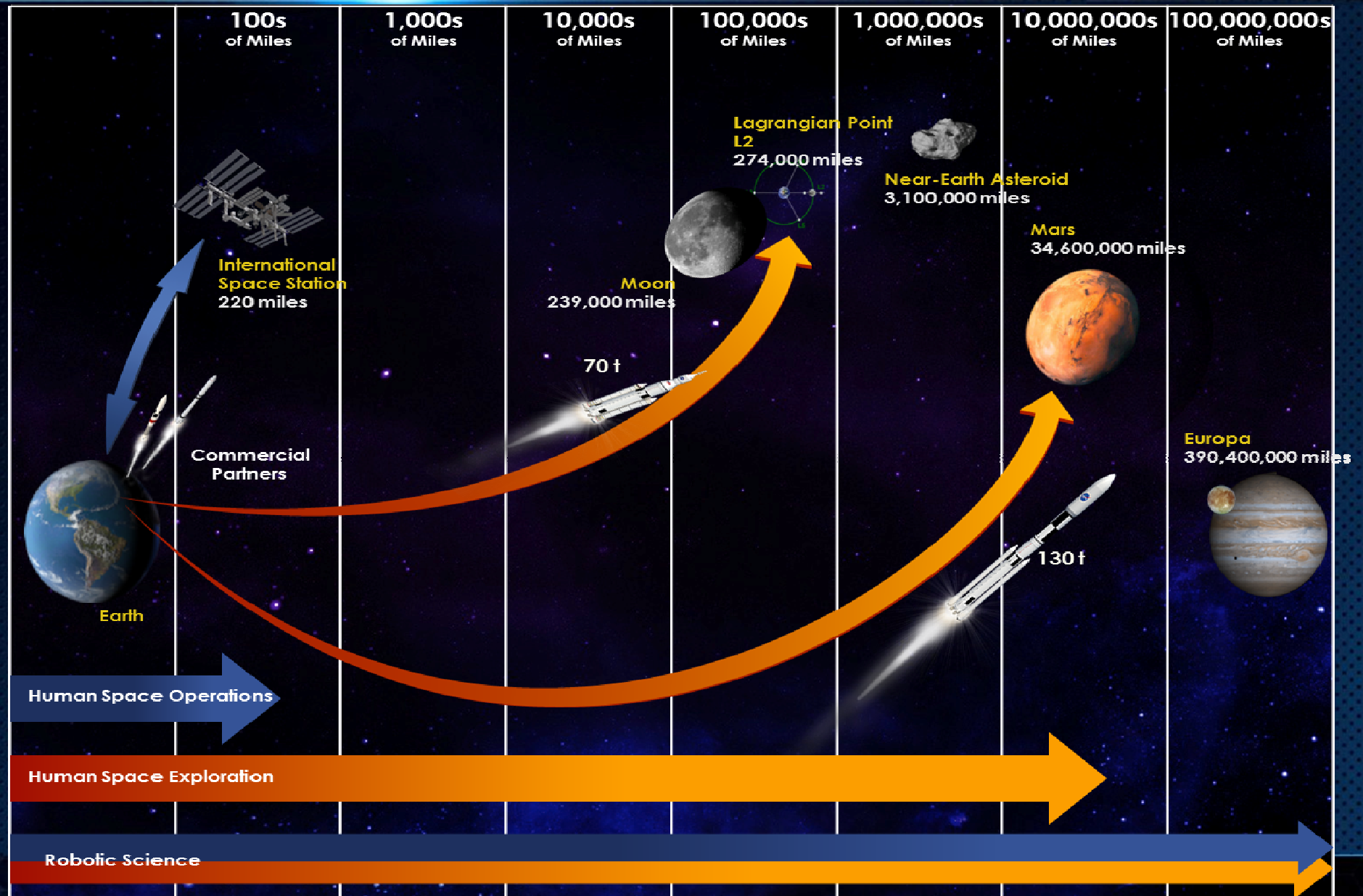
National Aeronautics and  
Space Administration



Lockheed Martin has participated on all NASA  
missions to Mars over the last 40 years!



# Exploration Destinations





# Lockheed Martin Contracts

## Areas of Innovation

- **Cargo Mission Contract (CMC) and Antarctic Support Contract (ASC)**
  - *Adaptability and Flexibility*
- **Integrated Mission Operations Contract (IMOC)**
  - *Technology Reuse*
- **Facilities Development and Operations Contract (FDOC)**
  - *Software and Processes*
- **Human Health and Performance Contract (HHPC)**
  - *Research/Operations Partnering*
- **Orion Contract**
  - *Space Vehicle Design/Development*



# Cargo Mission Contract (CMC)

**Mission:** Perform analytical and physical processing activities to support pressurized cargo requirements for visiting vehicle flights to and from the International Space Station:

- cargo mission planning and coordination
- stowage integration
- approximately 10,000 Decals, Placards and Graphics Production for all ISS hardware
- international and domestic shipping
- early return retrieval from landing site and containment of hazards
- capability to build hardware to support pressurized and unpressurized cargo transportation, as needed
- resources for ground freezers and transport to airport
- charter aircraft management for return to Houston

The Cargo Mission Contract keeps the ISS habitable, comfortable and full of technology, documenting every item going into space and returning.

CMC has responded with flexibility and ingenuity to rapid changes in manifests to keep the space station crew supplied with critical items and support scientific research

<b>45K</b>	Individual pieces of flight crew equipment processed since 2011
<b>95K</b>	Pounds of space station supplies traveling more than 800,000 miles
<b>3M+</b>	Items destined for ISS that Lockheed Martin warehouses and maintains



# Innovation Spotlight: CMC

## *Adaptability and Flexibility*

### **Challenge: Mechanical properties of packing materials**

#### **Innovative Solution:**

- Developed a method for comparing strength of cardboard shipping containers to wood shipping containers. Resolved customer concern about cardboard containers.
- Used mechanical properties of packing foam to resolve negative margin of safety for ISS Locker
- Performed analysis to determine the foam thickness requirements to attenuate transportation shock loads



### **Challenge: Thermodynamic problems**

#### **Innovative Solution:**

- Conducted thermal conductivity test to determine temperature of packed hardware exposed to elevated temperatures during shipping.
- Conducted system level moisture permeability test to determine relative humidity within packaging of hardware exposed elevated humidity.



# Innovation Spotlight: CMC

## *Adaptability and Flexibility*

**Challenge: Improve Packing Efficiency and Build Artificial Intelligence for Future Packing Configurations**

**Innovative Solution:**

- Re-purposed COTS freight packing software to automate generation of packing layouts for space flight hardware
- Tool can be customized to maximize packing density or crew unpacking efficiency



**Challenge: Provide Transparency to Customers while Eliminating the Need for On-site Reviews**

**Innovative Solutions:**

- Incorporated COTS image capture software merged with custom software to catalogue hardware imagery
- Photos are available in an easily searchable web browser to allow customer insight into operations



**Challenge: Safety assessments**

**Innovative Solution:**

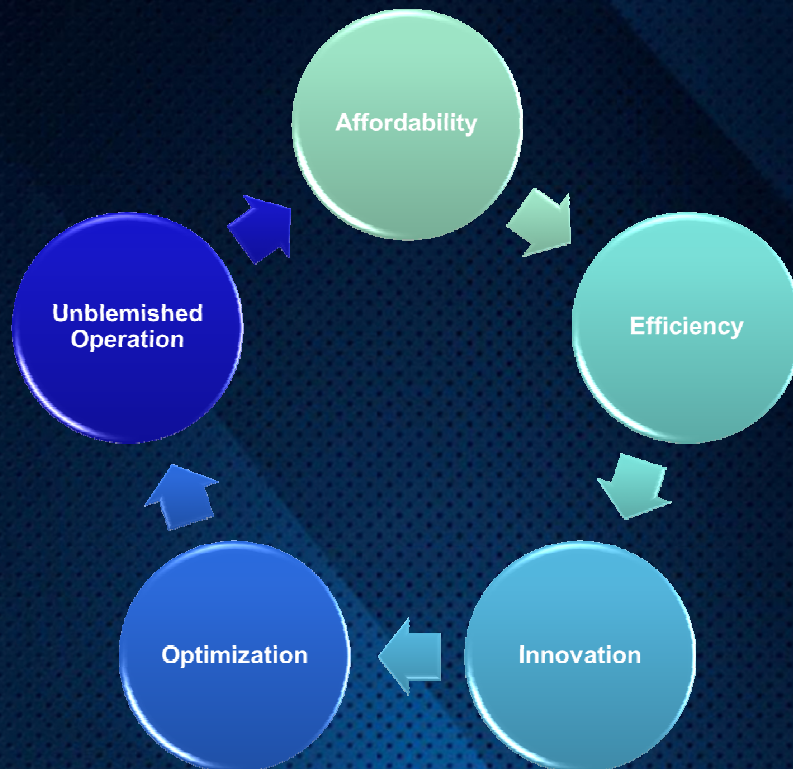
- Performed stress analysis of overhead beam for installation of hoist for lifting flight hardware
- Performed analysis to support design of shield around foam cutting machine for protection of personnel



# Innovation Spotlight: CMC

## *Adaptability and Flexibility*

- CMC has engaged in 50+ Structured Improvement Activities (SIAs) since contract start
- Average is 5.5 SIAs per award fee period



AF Period	Date	Number of SIAs
1	2/11-9/11	6
2	10/11-3/12	1
3	4/12-19/12	5
4	10/12-3/13	3
5	4/13-9/13	7
6	10/13-3/14	4
7	4/14-9/14	7
8	10/14-3/15	7
9	4/15-9/15	10

*Operating Excellence*



# Antarctic Support Contract (ASC)

**Mission:** Resupply the National Science Foundation (NSF)-managed U.S. Antarctic Program, the national program of scientific research in Antarctica.

- McMurdo Station, located on Ross Island, is the logistical hub for the U.S. research sites, as well as those of other nations.
- The bulk of McMurdo's supplies are delivered by ship.(6 million gallons of fuel and 6 million pounds of cargo).
- The cargo vessel loads about 5 million pounds of scientific samples, used equipment, recyclables, and waste for the return trip to the U.S. Research samples are often irreplaceable, thus outgoing cargo is as important as incoming cargo.
- The biggest challenge is the relatively short season during which travel to the scientific stations is feasible.
- A variety of transportation modes are required before supplies can be loaded onto the research vessel, and the final leg involves a 4-day crossing through some of the roughest seas on the planet.



# Integrated Mission Operations Contract (IMOC)

**Mission:** Plan, Train, and Fly human spaceflight services

- Provide mission and flight crew operations support for the International Space Station and future human space exploration.
- Includes ISS mission and flight crew operations preparation; crew, flight controller, instructor, and analyst training; as well as real-time mission execution support activities
- Space flight operations capability development and execution for emerging programs, including the Orion Multi-Purpose Crew Vehicle Program, the Space Launch Systems Program, the Commercial Crew Program, cargo resupply, and advanced technology and research programs





# Innovation Spotlight: IMOC

## Technology Reuse

**Challenge:** On ISS, air bubbles infiltrated the potable water bus which resulted in various issues. The filters become clogged by air, which results in the inability for crew to access drinkable water, as well as air in the water causing issues with the WHC's sensors, rendering the WHC unusable.

- To mitigate the air bubbles that are introduced into the system, the crews perform a degas of the CWC-I's which is time consuming.

**Innovative Solution:** IMOC personnel identified that expired Microbial Removal Filter's (MRFs) could be used to prevent air from entering the potable water bus by repurposing them as a makeshift gas trap, thus eliminating the continued need for degassing.

- Tests performed onboard ISS were successful, and future manifests of the MRF's are planned in order to make this part of nominal ops. We now have a more stable configuration and are saving hundreds of hours of crew time over the life of the ISS.



# Facilities Development and Operations Contract (FDOC)

**Mission:** Provide support for the hardware, software, data and display systems used to train for and execute all human spaceflight missions supported by the Flight Operations Directorate.

- Flight controllers monitor the systems/software on board, as well as the space crew's activities, health and safety. This group of dedicated team members meticulously check each system to insure they are working as planned.
- The flight control teams consists of experienced engineers, technician, and ground crews that are on duty 24/7 and 365 days a year.





# Innovation Spotlight: FDOC

## *Software and Processes*

- Mission Control Center Upgrade (MCC21)
  - Upgrade the architecture and technology to provide secure, flexible support to the ISS and new missions
  - Improve the environment and toolset available to the Flight Control Team
  - Enable operations by a smaller team, at 50% of 2008 operations costs, through the use of dramatically increased automation.
- **Innovations**
  - Use of Virtual Machine architecture in the MCC
  - Security with accessibility – created a multi-layered secured facility without compromising the ability of users to work remotely
  - Customized Agile development approach - enabled the development and integration of 2.6 million lines of code, supported customer involvement, continuous discovery and resolution of problems, and quick design decisions.
  - Integrated test approach - breaking organizational boundaries allowed requirements verification and system validation to be conducted in parallel
  - Integrated plot back-fill via Ops History Streaming
    - the streaming service with plot backfill may have application within the medical domain (e.g., EKG plots)
  - Fast facility build-out (6 months down to 8 weeks)



# Human Health and Performance Contract (HHPC) (Subcontract to Wyle Labs)

**Mission:** Support NASA/JSC Human Health and Performance Directorate (HHPD) in understanding the space frontier and the opportunities, capabilities, and limitations of humans living and working in that environment. This is implemented by human space research both in flight and through ground analogs. The HHPC team specializes in:

- payload development
- flight & ground hardware development
- human factors engineering
- systems engineering & integration
- food systems development
- mission operations
- space radiation analysis
- telescience operations
- data archival





# LM Contribution to HHPC

- World Class Subject Matter Experts at JSC
  - Direct support to NASA for ISS, Orion, and Commercial Programs, as well as the Human Research Program
- LM Fellows at JSC
- Lean Six Sigma Black Belts and practitioners at JSC
- LM Corporate Reach-back
  - Collaboration and innovation tools
  - Innovation Centers
  - Skunk Works® and related advanced technology investments

*More info provided in Wyle HHPC presentation*



# Innovation Spotlight: HHPC

## *Research/Operations Partnering*

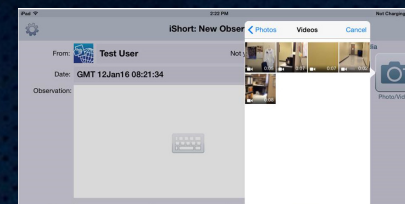
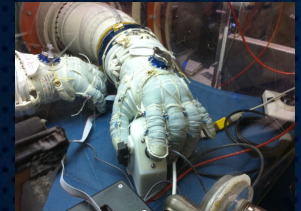
- Researchers and operations personnel typically live and work in different worlds.
  - Their processes and approaches to problems are very distinct
- Well-planned partnerships between these teams can be mutually beneficial and lead to results that matter!
  - Development/Ops teams must compromise in terms of increased schedule, but gain....
    - Research-based prototypes that can be used for down-select decisions in preparation for project-specific evaluations
    - Higher-quality, data-driven decisions
    - Standards and requirements that can be applied across projects
  - Researchers must compromise in terms of decreased experimental control, but gain...
    - Better understanding of the real-world environment and issues
    - Opportunities to conduct higher-fidelity testing
    - Ability to produce solutions that have an impact
- The Space Human Factors Engineering (SHFE) team, within the Human Research Program has worked hard to increase integration.



# Space Human Factors Engineering (SHFE)

## Research/Operations Partnering

- Cursor Control Device for Orion
  - Crew Interface Rapid Prototyping Laboratory and SHFE
  - Cursor Control Device Test Battery for evaluation (NASA Tech Release)
- Electronic Procedures Research
  - Crew Interface Rapid Prototyping Laboratory, TRAC Labs, Honeywell, and SHFE
  - Leveraging 2 existing procedures systems
  - Results could benefit these systems as well as future systems
- Industry Consortium
  - Partnering with an oil/gas/energy consortium to share common issues/solutions related to procedure use
- Most Recent New Technology Tools
  - Fine Motor Skills Test Battery
  - Space Habitability Observation Reporting Tool (iSHORT)
    - NASA Tech Releases
    - First time iPads used for science on ISS
    - Potential Earth Benefits

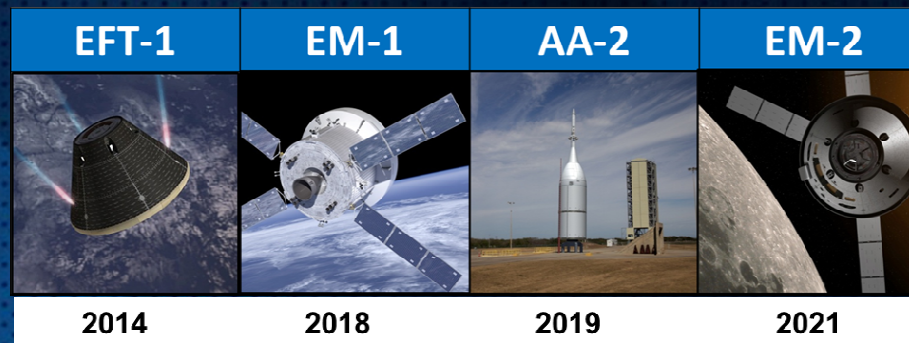




# Orion Multi-Purpose Crew Vehicle (MPCV)

Mission: Build the Orion Multi-Purpose Crew Vehicle, NASA's first spacecraft designed for long-duration, human-rated deep space exploration.

- Orion will transport humans to interplanetary destinations beyond low Earth orbit, such as asteroids, the moon and eventually Mars, and return them safely back to Earth.
- The Orion program will enable NASA to:
  - Carry out a robust human and robotic exploration program that is both sustainable and affordable
  - Develop the innovative technology, knowledge, and infrastructure needed to support more challenging human space exploration missions
- Exploration Flight Test-1 successfully completed flight objectives and traveled farther than any human-rated spacecraft in more than 40 years.





# Innovation Spotlight: Orion

## Space Vehicle Design/Development

- Orion traveled farther than a human-rated spacecraft has been in more than 40 years
- Exploration Flight Test-1 successfully completed flight objectives
- Lessons from design, manufacturing, flight, and recovery phases influencing next missions

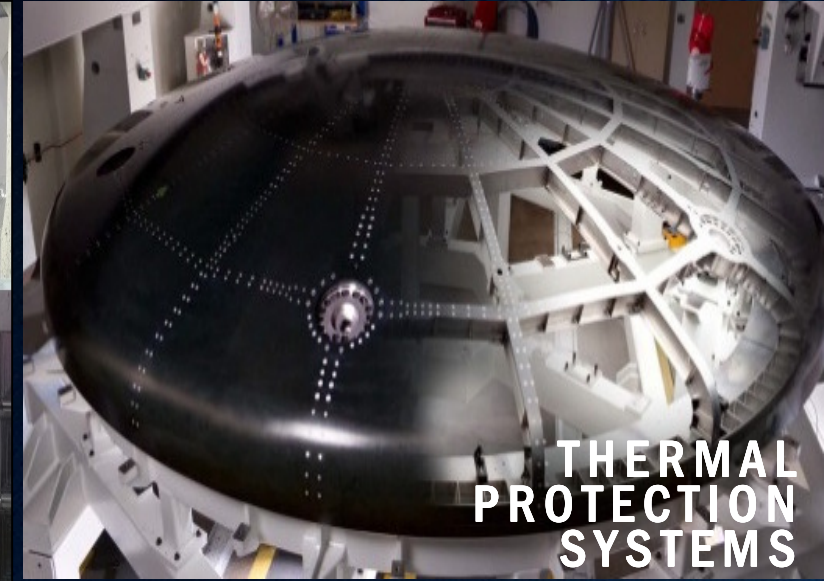
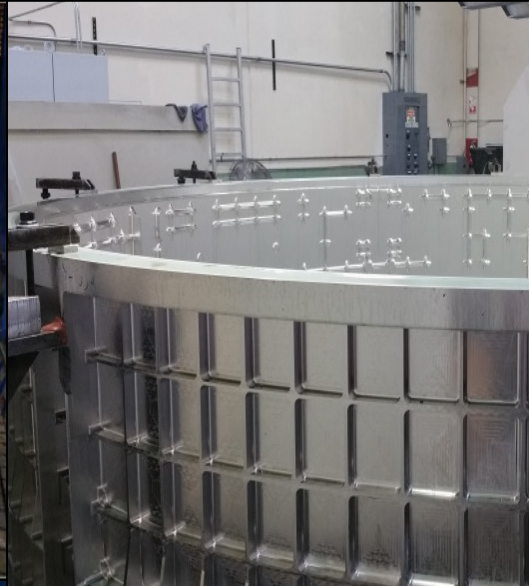
*Note: This Earth image was taken from Orion's 3600-mile apogee during Exploration Flight Test-1.*



# Orion Technology Innovations



**ADVANCED  
LIGHTWEIGHT  
STRUCTURES**



**THERMAL  
PROTECTION  
SYSTEMS**



**RISK MITIGATION  
FACILITIES**



**LIFE SUPPORT  
SYSTEMS**



# Orion Innovations

- Next generation advanced electronics and power systems
- Advanced materials and processing
- Communication/data handling
- Several “firsts” in spaceflight history for software and the computing accuracy and speed.
  - The Orion Gigabit Ethernet is 1000 times faster than Shuttle and ISS data networks.
  - Orion's master computer provides significantly faster computing speed over other human space flight vehicles:
    - 4000 times faster than Apollo
    - 400 times faster than Shuttle
    - 25 times faster than International Space Station
  - The communications system provides functionality of 4 radios in one allowing communication with Multiple space vehicles, International Space Station and Tracking & Data Relay Satellite System (TDRSS) or any combination of the above
  - Orion's 'glass' cockpit provides fully redundant crew controls and displays with over 60 graphic display formats and interactive electronic procedures - a first in spacecraft history.



