



# **Exploration Research and Technology Programs**

**Overview for “NASA Days” in Puerto Rico**

Greg Clements  
August 2018



# Exploration Research and Technology (ER&T) Programs

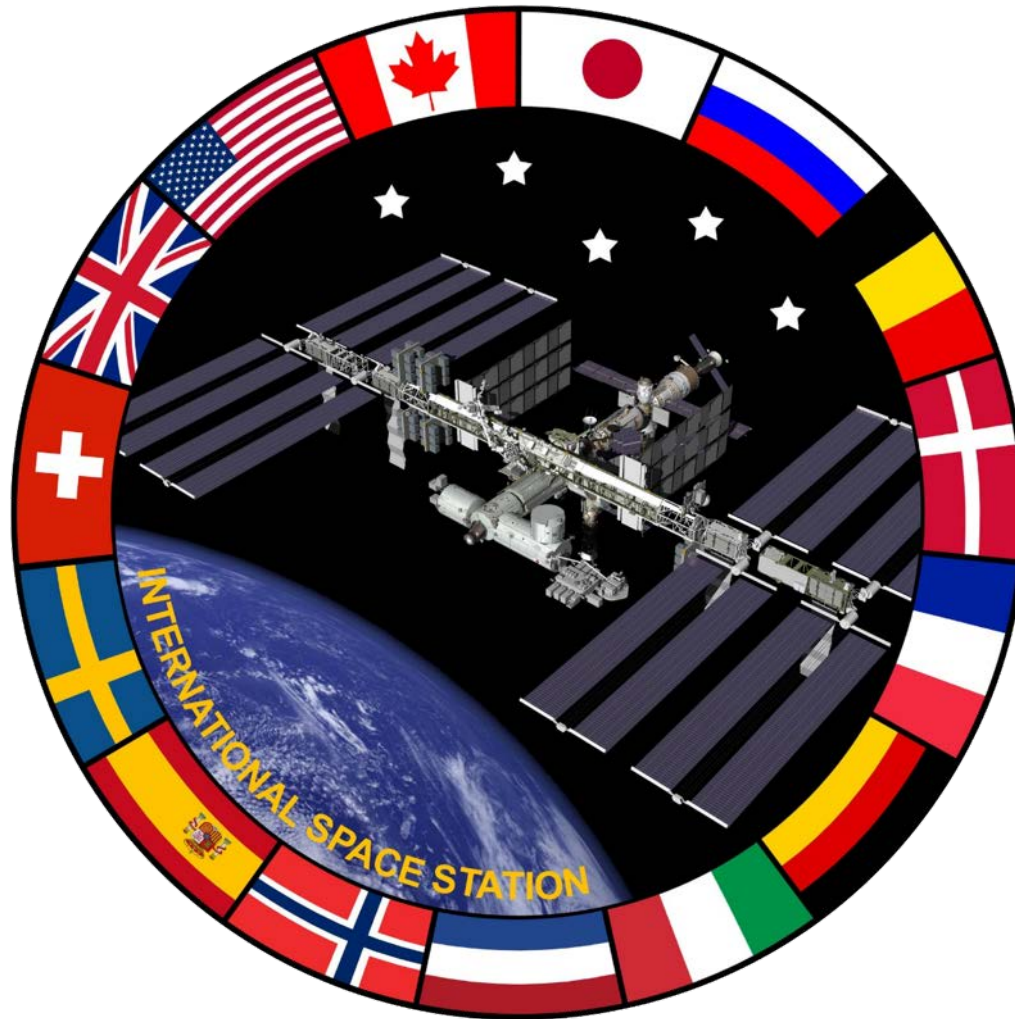


John F. Kennedy Space Center

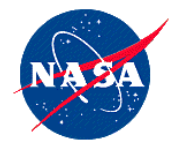
- ER&T performs work at KSC for 6 NASA programs and mission directorates
  - International Space Station (ISS)
  - Space Life and Physical Science Research Applications (SLPSRA)
  - Human Research Program (HRP)
  - Advanced Exploration Systems (AES)
  - Space Technology Mission Directorate (STMD)
  - Center Management and Operations (CMO)
  
- ER&T is responsible for the management of approximately
  - \$ 100M annually
  - 180 NASA Civil Servants



# International Space Station Program Support







# ISS On Orbit



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# Current Crew Transportation to ISS



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Since the Space Shuttle Program was retired in 2011, we rely on Russian Soyuz launches from Kazakhstan to get Space Station mission crews to and from the ISS





# Future Crew Transportation to ISS

Starting in 2019, through NASA's Commercial Crew Program, astronauts will travel to/from the ISS on US commercial spacecraft launched from Florida

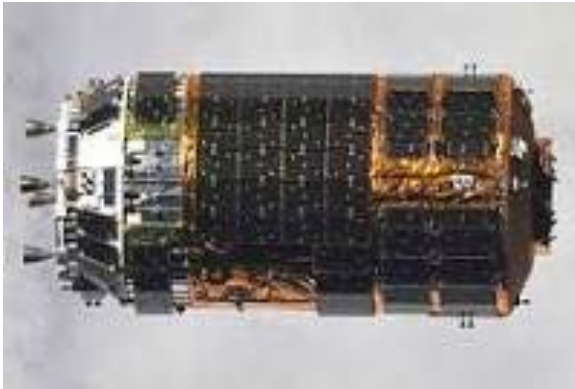


Boeing *“Starliner”*



SpaceX *“Dragon”*

# Cargo Transport to ISS



Japanese Space Agency  
(JAXA) “*Heavy Transfer Vehicle*”



Russian “*Progress*”



SpaceX “*Dragon*”



Orbital/ATK “*Cygnus*”



Sierra Nevada  
“*Dream Chaser*”  
(Future - 2021)



# ISS Launch Support



- Processing, servicing, and checkout of pressurized and unpressurized ISS Orbital Replacement Units and Flight Support Equipment
- Nitrogen Oxygen Recharge System (NORS) servicing and fill for flight
- Host support for unpressurized Flight Releasable Attachment Mechanism Utilization payloads
- Host role support for International Partners and Commercial Resupply Contracts

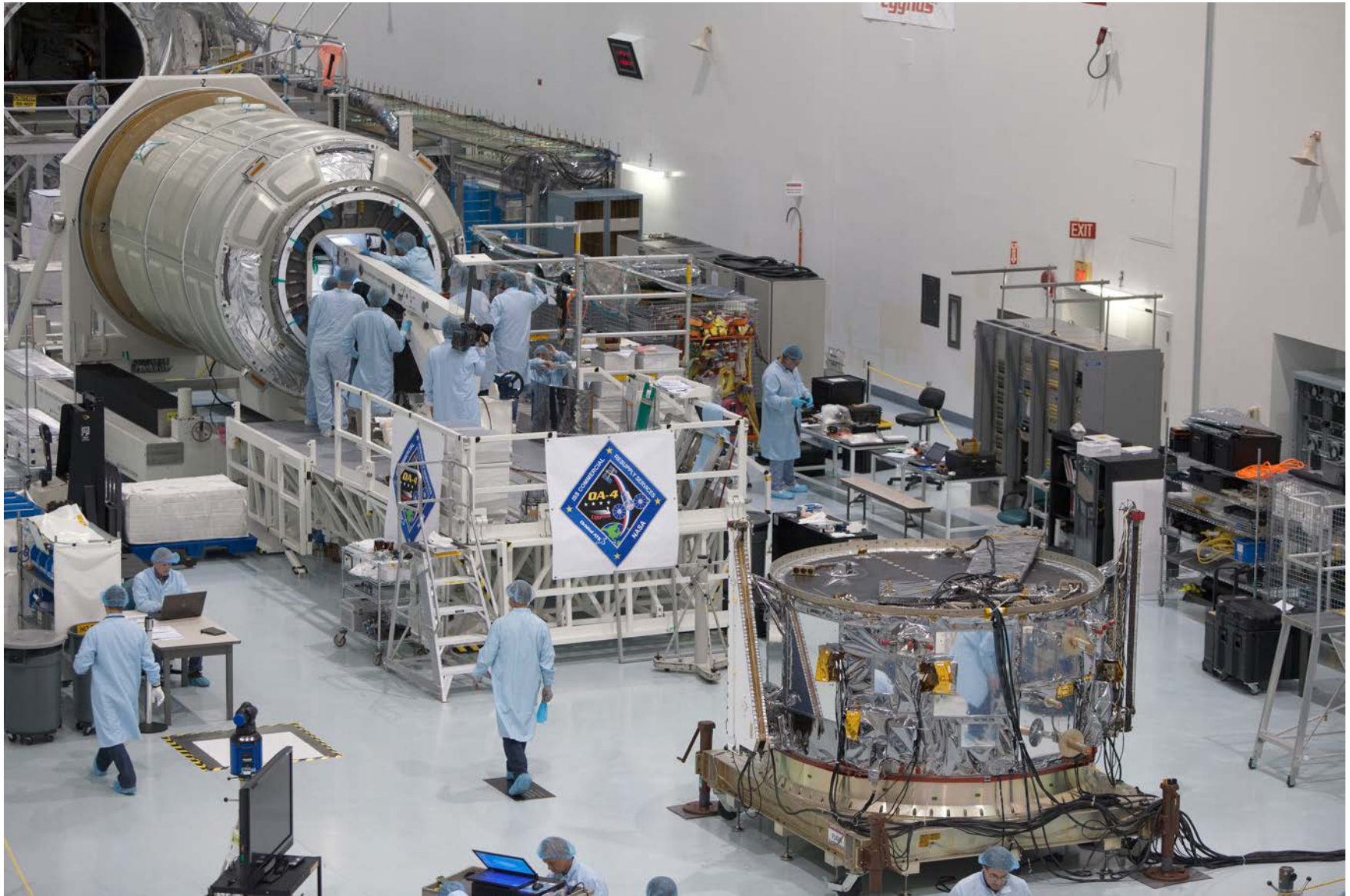


# International Docking Adapter



# Orbital ATK “Cygnus” in SSPF Highbay

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# ISS Logistics

- KSC is the primary warehousing site for ISS Spare Parts and Materials, and is one of the primary Logistics Depots for the ISS Program
- KSC provides shipping and transportation (including international) for ISS flight hardware, equipment, and materials
  - Packaging
  - Shipping and Receiving
  - Transportation
- Orbital Replacement Unit and Payload Processing Support



SSPF Freezer



Automated Forklift



Bulk Storage

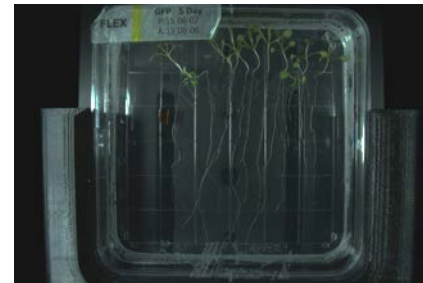
# KSC Transportation





# ISS Utilization

- KSC provides support to ISS Primary Investigators (PIs) and Payload Developers to enable their preparation and successful utilization of the ISS as a world class laboratory
  - Mission Integration and Operations Support to customers performing research and experiments through standardized Multi Use Experiment Platforms
    - Biological Research In Canisters (BRIC), VEGGIE, and Kennedy Fixation Tubes (KFTs)
  - Development of future Multi-Use Hardware
    - Advance Plant Habitat (APH) – now on orbit awaiting first science
    - SPECTRUM Multispectral Fluorescent Imager - (under Development)
  - Ground Processing Support to PIs and science teams to prepare payload for flight
    - Operate and Maintain offline labs and ISS Environmental Simulation Chambers



# Space Station Processing Facility

## ■ High Bay

- 38,000 ft<sup>2</sup> Class 100K clean work area
- 8 footprints, completely reconfigurable
- Available commodities include 208V/480V power, chilled water, GN<sub>2</sub>, GHe, LN<sub>2</sub>
- Two 30-ton electrical bridge cranes with 50-ft hook height



## ■ Intermediate Bay

- 17,000 ft<sup>2</sup> Class 100K clean area
- Two 5-ton electrical bridge cranes with 25-ft hook height

## ■ Airlock

- 5000 ft<sup>2</sup> Class 300K clean area
- 15-ton electrical bridge crane with 50-ft hook height

## ■ Administrative Space

- Office Space for approximately 1000 employees
- 25 Conference Rooms

## ■ Specialty Areas

- Off-Line Processing Rooms
- 19 Science Labs/Hardware Labs, 3 Central Services Labs
- 9 control rooms located on raised floor areas
- Vapor Containment Facility to house liquid anhydrous ammonia

## ■ Special Provisions

- Uninterruptable Power Supplies, with Redundant Power Feeds
- Dual Automatic Starting Backup Generators
- Portable Backup HVAC Chiller



# Gateway Notional Architecture

## GATEWAY

An exploration and science outpost in orbit around the Moon

A recently announced new Program for NASA is the Gateway – an outpost moving between low earth orbit and lunar orbit

### Power and Propulsion Element:

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



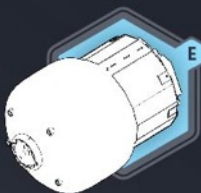
### ESPRIT:

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 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.



### NASA-led architecture and integration

U.S.

International

TBD: U.S. and/or International

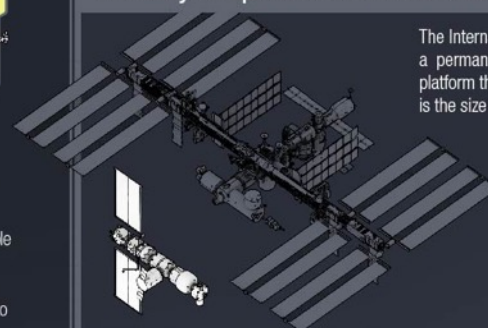
### Orion:

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

### 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.







# Research and Technology at KSC



We are currently working over **130** research projects, space grants, outreach, and technology development activities, including flight experiments on the ISS



**Human Research Program (HRP)**

Our research and technology portfolio covers five areas



**Space Life and Physical Sciences Research and Applications (SLPSRA)**



**Space Technology Mission Directorate (STMD)**



**KSC Center Management and Operations (CMO)**



**Advanced Exploration Systems (AES)**





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**Human Research Program (HRP)**

**Human Research Program (HRP)**, which investigates and mitigates the highest risks to human health and performance in order to enable safe, reliable, and productive human space exploration



**Space Life and Physical Sciences Research and Applications (SLPSRA)**



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**Human Research Program  
(HRP)**

SLPSRA includes the [Space Biology Program](#), which solicits and conducts research to understand how biological systems accommodate to spaceflight environments, and the [Physical Sciences Program](#), which solicits and conducts research to understand how physical systems respond to spaceflight environments, particularly weightlessness



**Space Life and Physical Sciences  
Research and Applications  
(SLPSRA)**



**Space Technology Mission  
Directorate (STMD)**



**KSC Center Management and  
Operations (CMO)**



**Advanced Exploration Systems  
(AES)**



# Research and Technology at KSC



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**Human Research Program (HRP)**

AES pioneers new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond low-Earth orbit.

AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development.



**Space Life and Physical Sciences Research and Applications (SLPSRA)**



**Space Technology Mission Directorate (STMD)**



**KSC Center Management and Operations (CMO)**



**Advanced Exploration Systems (AES)**



# Research and Technology at KSC



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**Human Research Program (HRP)**

**STMD** rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise.

A variety of STMD grants, programs, solicitations, prizes and challenges foster collaboration and innovation



**Space Technology Mission Directorate (STMD)**



**KSC Center Management and Operations (CMO)**



**Space Life and Physical Sciences Research and Applications (SLPSRA)**



**Advanced Exploration Systems (AES)**



# Research and Technology at KSC

We are currently working over 130 research projects, space grants, outreach, and technology development activities, including flight experiments on the ISS



**Human Research Program  
(HRP)**

**KSC CMO** supports a select number of research and technology initiatives that benefit and enhance the ongoing operations, programs, and mission of the Kennedy Space Center, the world's premier multi-user spaceport.



**Space Technology Mission  
Directorate (STMD)**



**KSC Center Management and  
Operations (CMO)**



**Space Life and Physical Sciences  
Research and Applications  
(SLPSRA)**



**Advanced Exploration Systems  
(AES)**



# Research and Technology at KSC



The next several slides show examples of KSC's research and technology activities

# KSC Animal Care Program

- KSC's Animal Care Program provides an IACUC (Institutional Animal Care and Use Committee) certified rodent research capability to support multiple ISS customer including CASIS, Russia, and JAXA
  - Operate the SSPF Science Annex
  - Animal housing and care
  - Laboratory and analytical support
  - Surgery and X-Ray
  - Data collection
  - Supplies and consumables

# Food Production Project Highlights

***“Enabling food production concepts for space exploration”***

- **Pick-and-Eat Salad Crop Study**

- Veg-04 EVT ground harvest performed on 1/24

- **New Crop Testing**

- Based on HRP nutritional guidance 16 new leafy greens are currently in evaluation

- **Water Delivery Test Bed**

- A Porous Tube Nutrient Development System (PTNDS) is nearing completion and will serve as the first candidate system to be evaluated

- **Gateway Plant Payload**

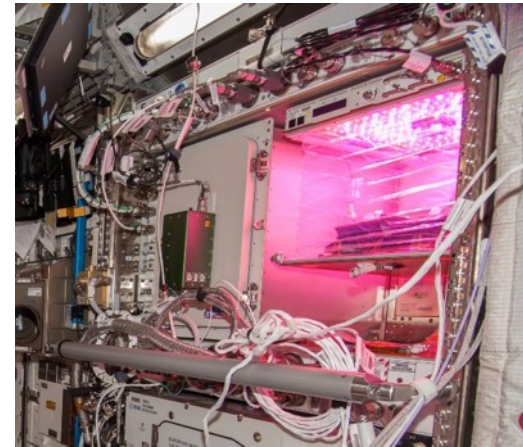
- Study the effects of deep space radiation and other environmental conditions







# VEGGIE





# Plans for Expanding Food Production in Space

## VEGGIE (0.15 m<sup>2</sup>) (Currently Operating on ISS)



## Double Rack Growth Unit (2.0 m<sup>2</sup>) (Currently in Development)

## Pressurized Garden Module (10 m<sup>2</sup>) (Expansion to ISS or Gateway)

# Trash to Gas

- The Trash to Gas project seeks to develop promising trash processing technologies for future spaceflight missions
- Evaluated different technologies:
  - Catalytic Wet Air Oxidation
  - Incineration/Gasification
  - Ozone Oxidation
  - Pyrolysis
  - Steam Reforming
  - Plasma Arc Gasification



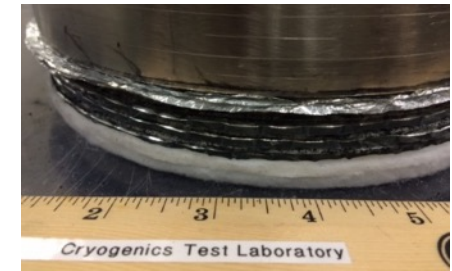
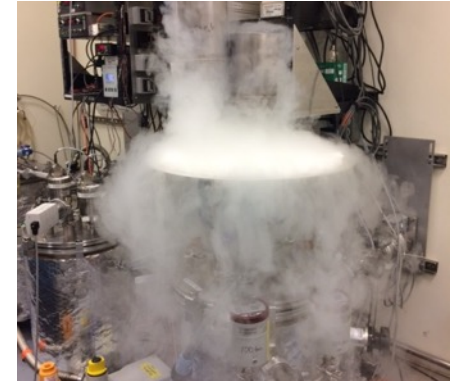
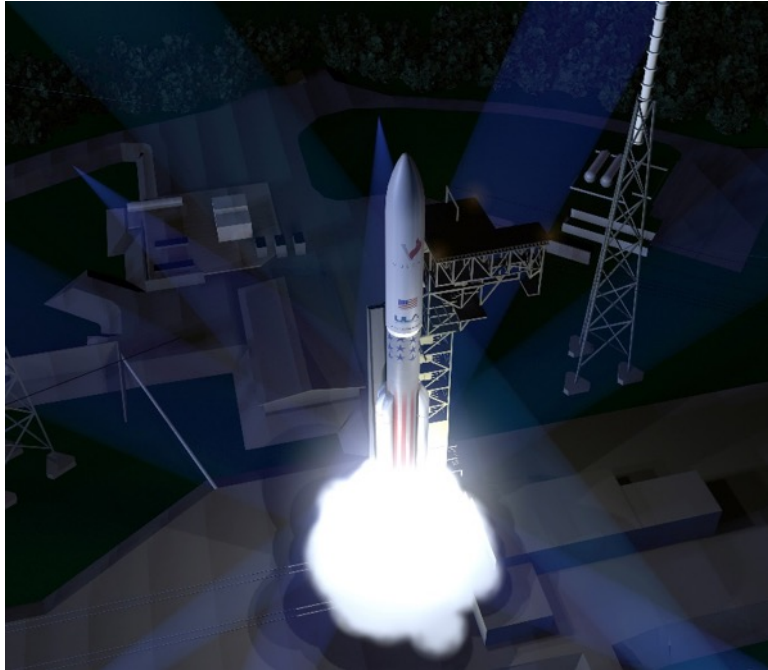
**Incineration/Gasification Team at Kennedy Space Center**



**Waste Storage on ISS**



# Windward Cryogenic Tank Insulation



- Problem: keep LH2 on-orbit one week or more
- Three-part problem: launch pad hold (760 torr), launch ascent, and in space (high vacuum)
- Developed new Tri-hybrid Layered Composite (TLC) thermal insulation system



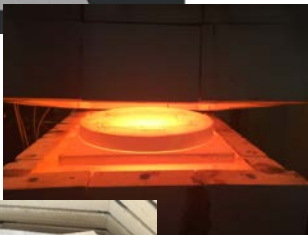
# Additive Construction Element Using In-Situ Materials



Top View



Bottom View



Robotic Paver Deployment Mechanism on PISCES Rover in Hawaii



VTVL Landing Pad in Hilo



6'x6'x8' guard shack accomplished at the US Army Research & Development Lab in Illinois



Dry Goods Feed System

Basalt Inter-locking Paver – modular design  
At 2150F, 3 times stronger than specialized concrete





# Regolith Advanced Surface Systems Operations Robot (RASSOR)

**MISSION: Mine Regolith & Deliver to a Processing Plant**





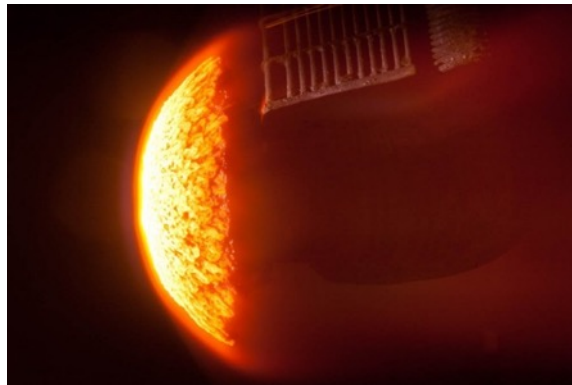
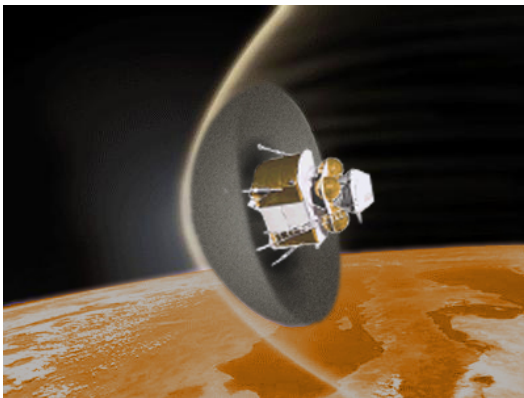
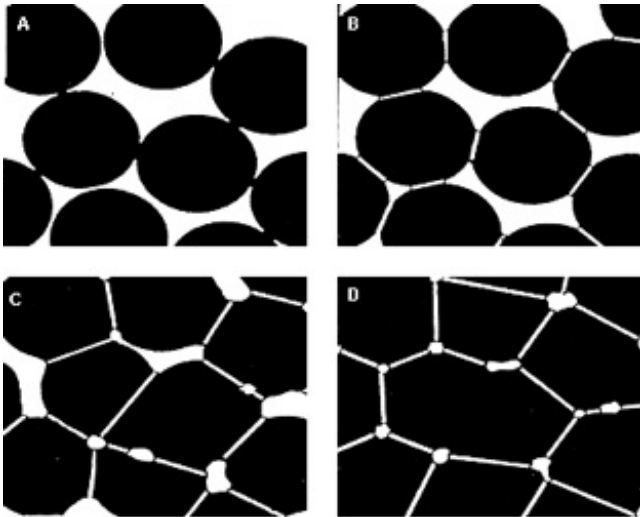


# 3-D Printing/Additive Manufacturing from Regolith-derived Materials



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Heating the moon dirt to just-below-melting temperatures (1200-1500 °C) makes the dirt stick together. Robotic 3D printers can then build walls of a habitat, or launch pads, paved roads etc.



**Regolith-derived heat shield** sample undergoing flame testing at ARC; regolith samples post-test; artist concept.

Image Credit: NASA/KSC



# Additive Construction Element Using In-Situ Materials



Environmental Protection



Images Courtesy  
of Dr. B. Khoshnevis,  
Contour Crafting, LLC

Complex Tool Path Development Allows Interior Walls



# NASA Spinoffs From ER&T



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- • **Aerogel Insulation Makes Thinner, Warmer Outerwear -**  
[https://spinoff.nasa.gov/Spinoff2018/cg\\_5.html](https://spinoff.nasa.gov/Spinoff2018/cg_5.html)
- • **High-Efficiency LEDs Grow Crops, Stimulate Alertness -**  
[https://spinoff.nasa.gov/Spinoff2018/ee\\_2.html](https://spinoff.nasa.gov/Spinoff2018/ee_2.html)
- • **Organic Compound Turns Toxic Waste into Harmless Byproducts -**  
[https://spinoff.nasa.gov/Spinoff2018/ee\\_1.html](https://spinoff.nasa.gov/Spinoff2018/ee_1.html)
- • **Plant Food for Space Grows Crops on Earth -**  
[https://spinoff.nasa.gov/Spinoff2018/ee\\_3.html](https://spinoff.nasa.gov/Spinoff2018/ee_3.html)
- • **Silicon Diode Sensor Tracks Extreme Temperatures -**  
[https://spinoff.nasa.gov/Spinoff2018/ip\\_6.html](https://spinoff.nasa.gov/Spinoff2018/ip_6.html)
- • **Spinoffs of Tomorrow - Self-Healing Wire Insulation and Autonomous Flight Termination System -** [https://spinoff.nasa.gov/Spinoff2018/sot\\_1.html](https://spinoff.nasa.gov/Spinoff2018/sot_1.html)





# Questions?