



Development of Flight Hardware at Marshall Space Flight Center

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Director, Space Systems Department
Engineering Directorate
Marshall Space Flight Center
April 12, 2019





Ames Research Center

Aerospace and
Small Spacecraft
Moffett Field, Calif.

Armstrong Flight Research Center

Aeronautical Research
and Testing
Edwards, Calif.

Jet Propulsion Laboratory

Deep Space Robotic
Rovers and Science Missions
Pasadena, Calif.

Johnson Space Center

Human Space Flight
Research and Operations
Houston, Texas

Stennis Space Center

Rocket Propulsion Testing
Bay St. Louis, Miss.

Michoud Assembly Facility

Large Vehicle
Manufacturing
New Orleans, La.

Glenn Research Center

Electric Propulsion and
Small Spacecraft
Technology
Cleveland, Ohio

Marshall Space Flight Center

Launch Vehicle Development,
Chemical Propulsion, and
Science Instrument
Development
Huntsville, Ala.

Goddard Space Flight Center

Science Missions
and Telescopes
Greenbelt, Md.

NASA Headquarters

Washington, D.C.

Langley Research Center

Aviation and Space Research
Hampton, Va.

Kennedy Space Center

Ground Operations
and Services
Cape Canaveral, Fla.

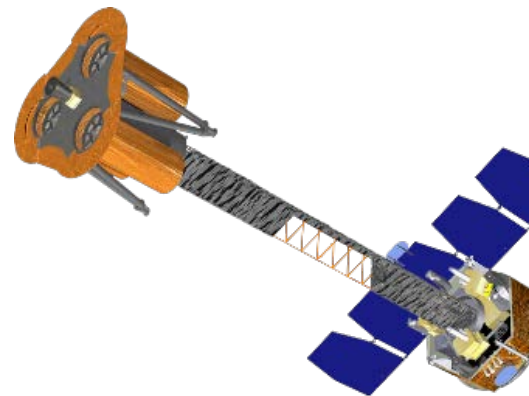
Marshall Space Flight Center

**Traveling To
and Through
Space**



**Living and
Working in Space**

**Supporting Agency
Mission Operations**



**Understanding Our
World and Beyond**

Marshall's Mission Areas

Earth



Commercial launch
Vehicles

Moon



Mars



In LEO

Commercial & International
partnerships

In Cislunar Space

A return to the moon for
long-term exploration

On Mars

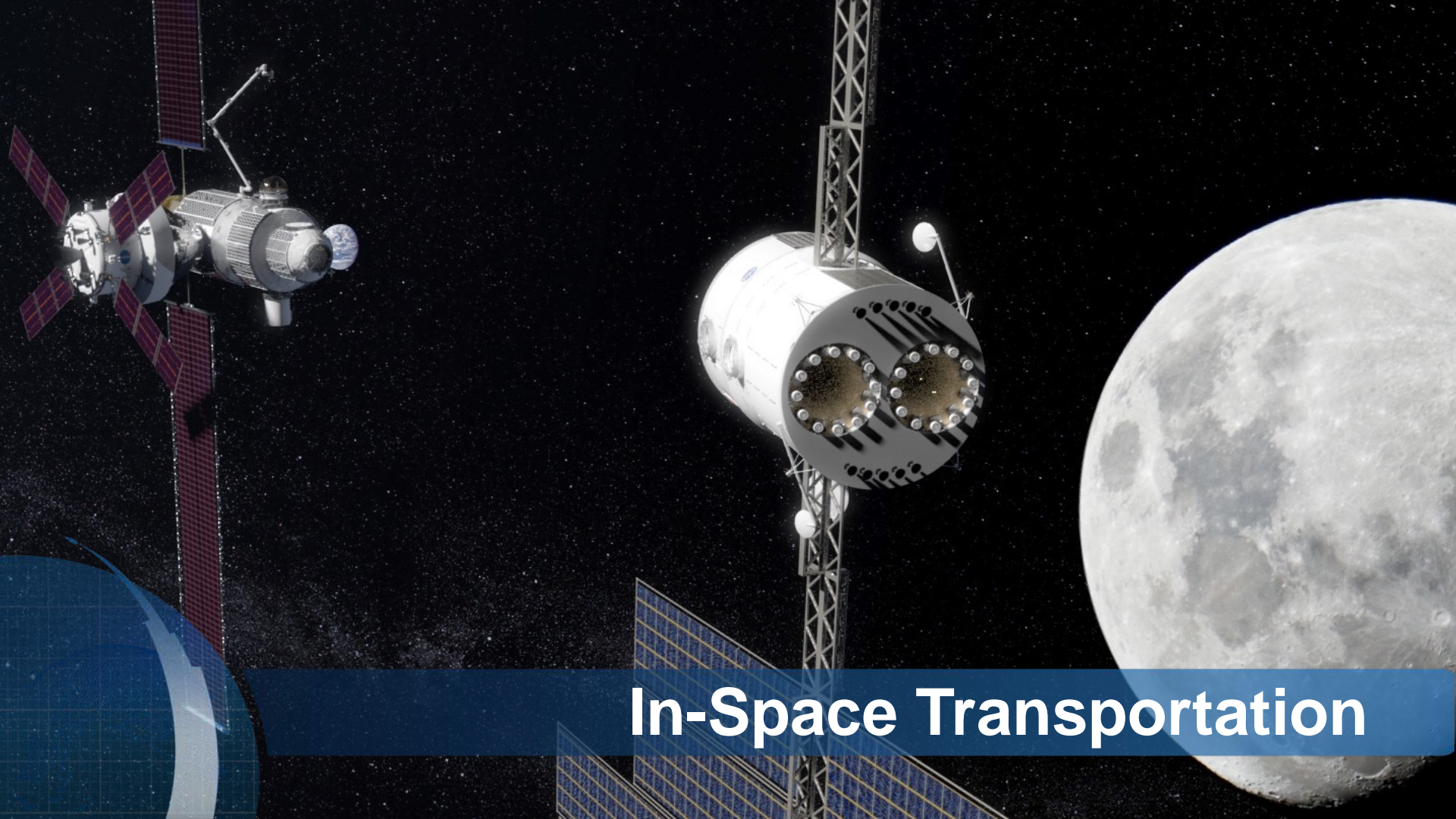
Research to inform future
crewed missions



Space Launch System



Michoud: Building the Next Generation Rocket



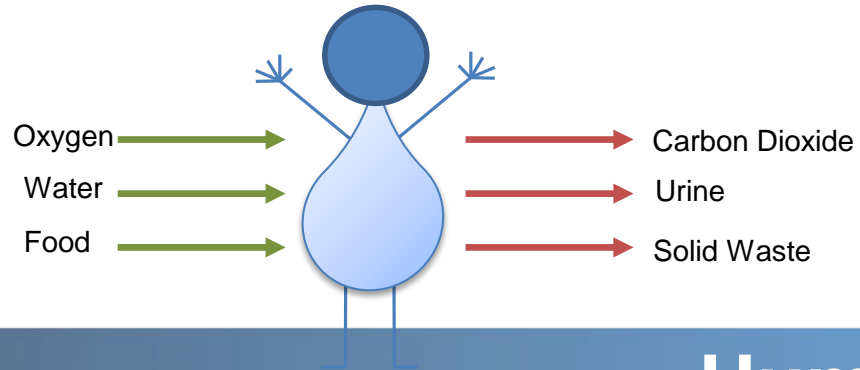
In-Space Transportation



Living and Working in Space

Definition:

“...ugly bags of mostly water.”
- *Microbrain (Star Trek Next Generation 1988)*



Humans



“Come with me if you want to live.”
- *The Terminator* (*Terminator*, 1984)

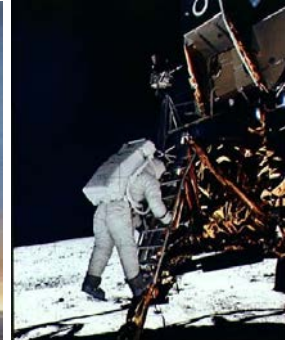
Daily Dose of Narcissism



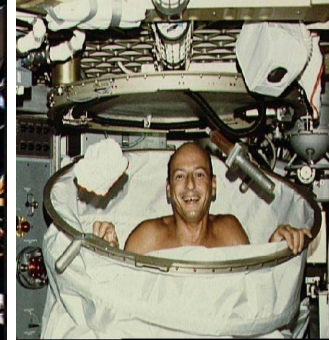
Mercury
Astronauts
1961-1963



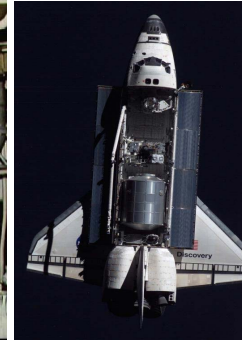
Saturn V
1968-1979



Lunar Module
1969-1972



Skylab
1973-1979



Space Shuttle
1981-2011



International Space
Station
1981-2011

Short = days to weeks

Mercury
Gemini
Apollo
Shuttle

Medium = months

Skylab
Cis-Lunar?
Mars Transit

Long = years

ISS
Lunar Surface
Martian Surface

Recycle



Mission Duration

Life Support Mission Definitions

Launch Costs

1lb Water ~\$33,000

1 gallon Water = 8.3 lbs

1 gallon Water = \$273,900

Crew Reqt's

0.66 gallons potable water
consumed/CM-day

0.24 gallons to electrolyze for
O₂/CM-day

Mission Cost

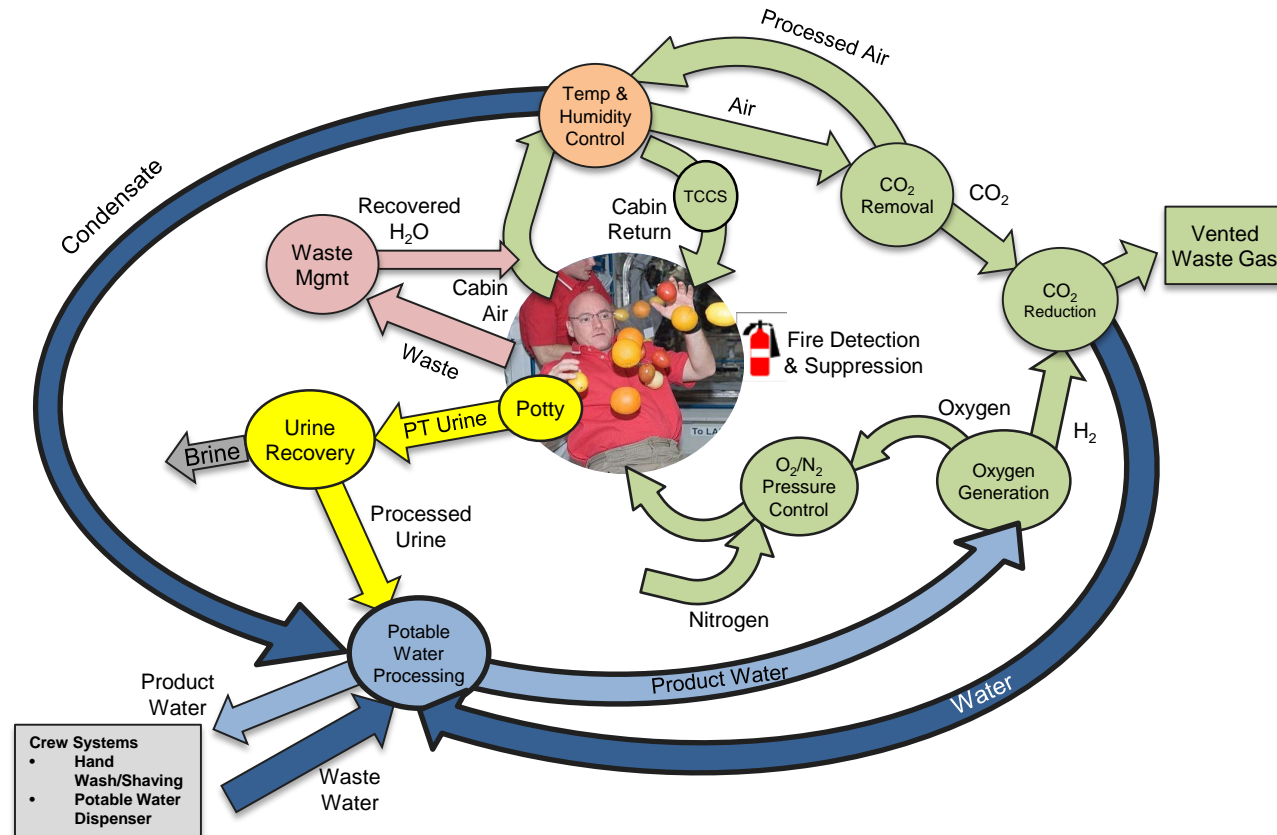
\$247k/CM-day

4-crew = \$1M/day

**\$1.1B for 3yr Mars
Mission with 4 crew**



Perspective



Life Support Today: ISS

- Continuously occupied since 10/01
- 90-180 day increments typical
- 6 crew typical
- Focus on resource recycling



Atmosphere Revitalization
System Rack
(Activated Feb 2001)



Oxygen Generation System Rack
(OGA Activation July 2007
Sabatier Activation June 2011)



Water Recovery System (WRS) Racks
1 and 2
(Activation March 2009)



Life Support Today: ISS



Future O₂ Recovery

Bosch:



CO₂ Decomposition:

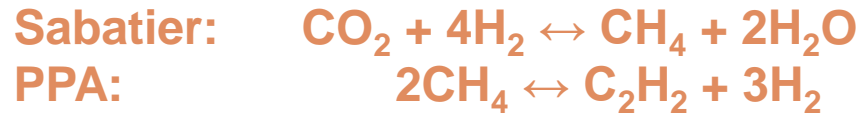


Co-Electrolysis:

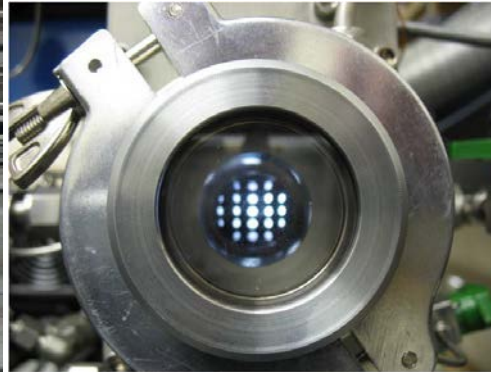


100% O₂
Recovery

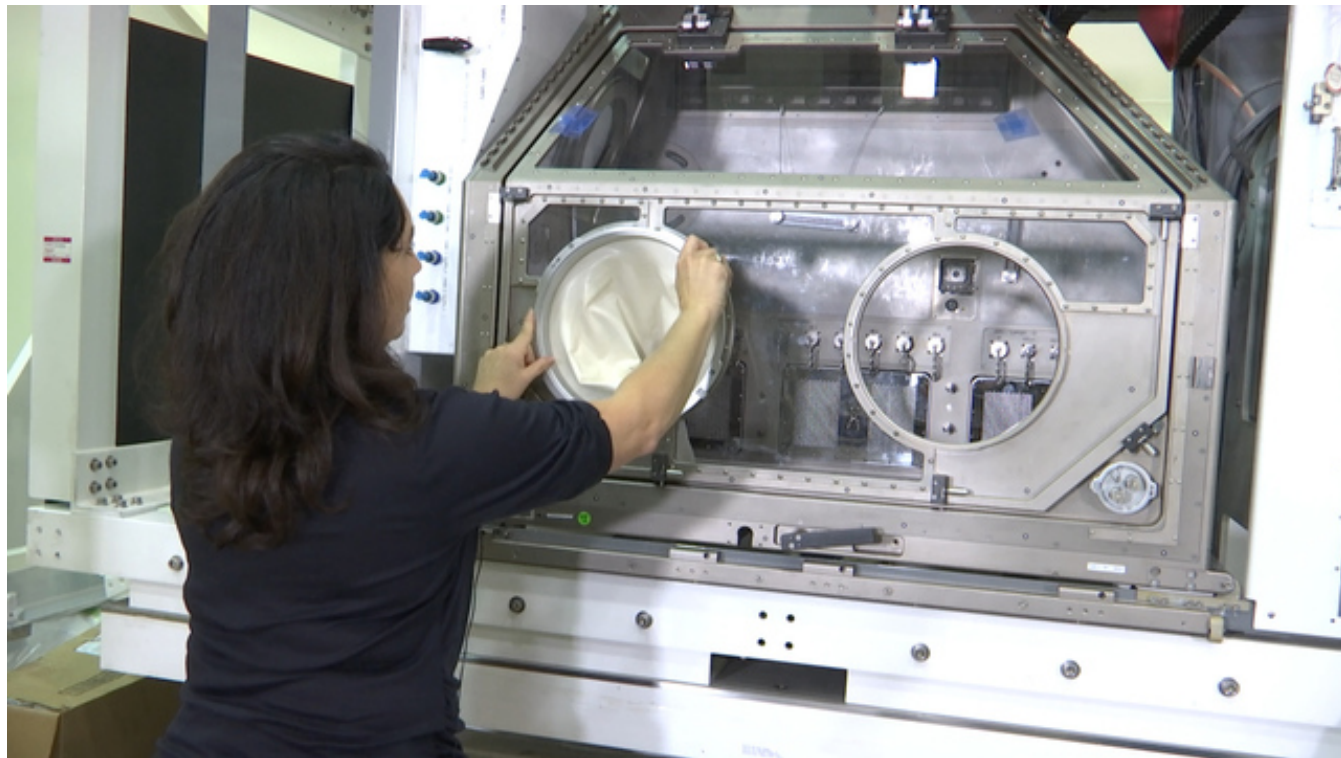




75-90% O₂
Recovery



PPA: O₂ Recovery Flight Exp




Life Science Glovebox



ISS021E006220

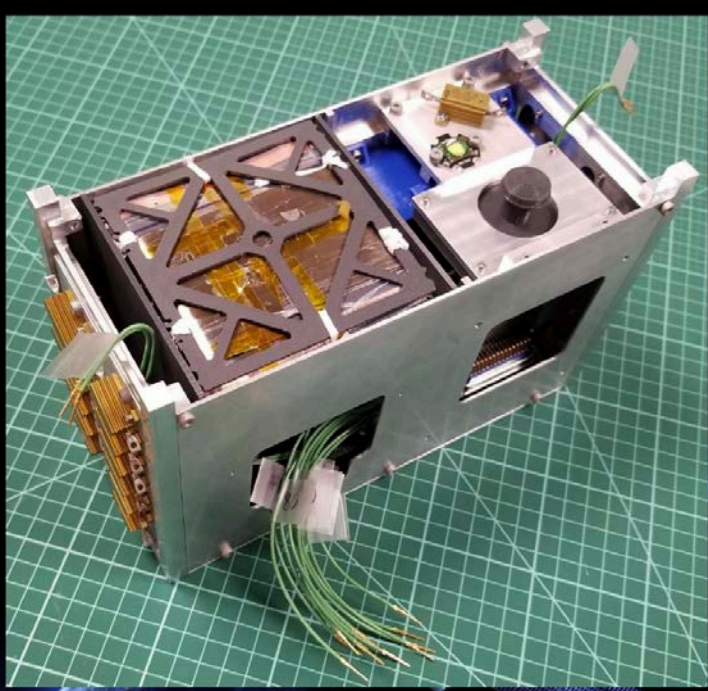


Material Science Research Rack

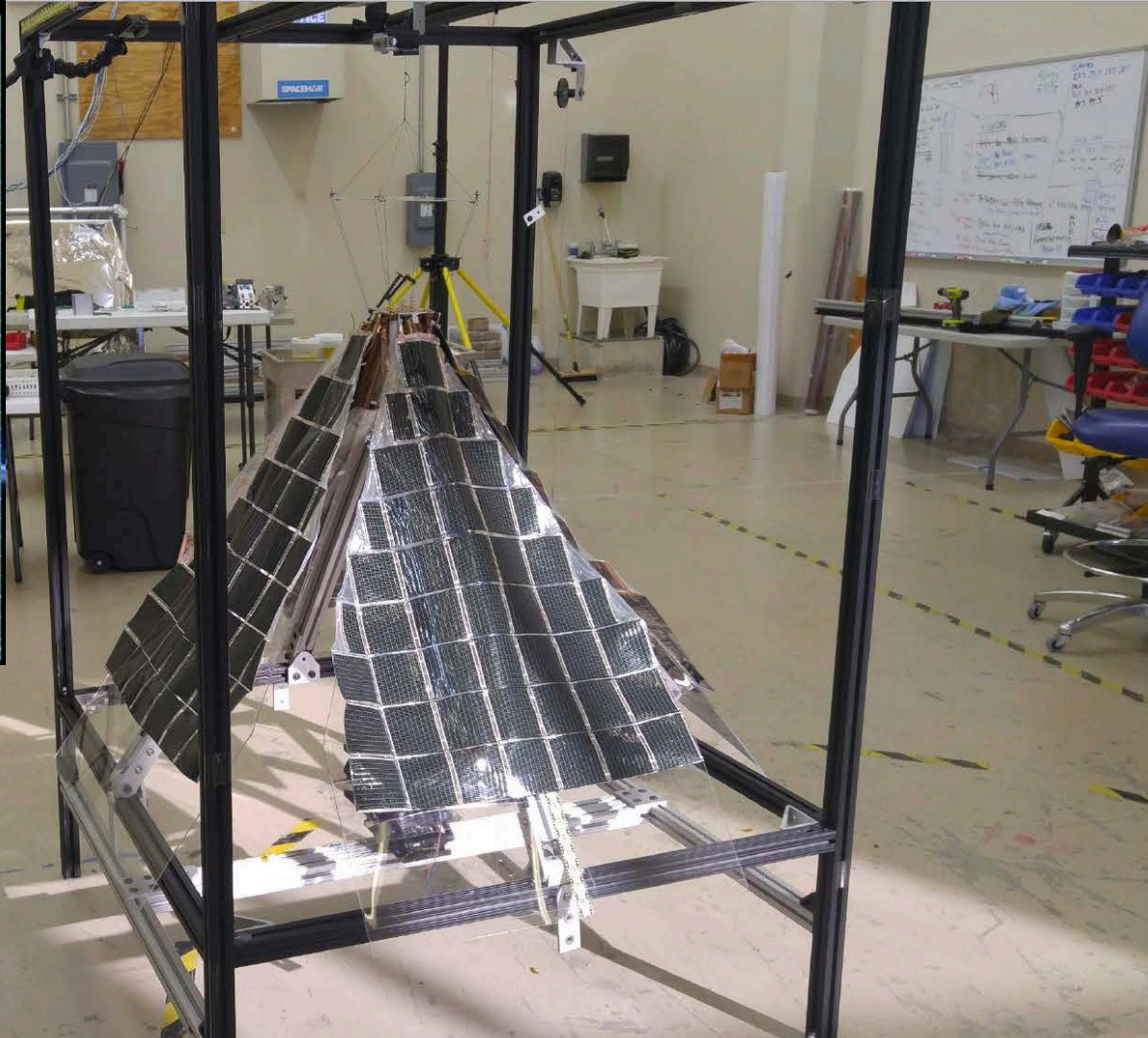
The image features a detailed illustration of the Imaging X-ray Polarimetry Explorer (IXPE) satellite in the vastness of space. The satellite is shown from a side-on perspective, with its long, rectangular solar panel arrays extended horizontally. These panels are white with a grid of blue photovoltaic cells. At the rear of the satellite, a complex instrument package is visible, featuring two large, cylindrical detectors mounted on a black frame. A bright, glowing red and purple nebula or cosmic cloud fills the background, with numerous stars scattered throughout. In the bottom left corner, a portion of the Earth's blue and green surface is visible, showing a grid pattern. The overall scene conveys a sense of advanced space exploration and scientific discovery.

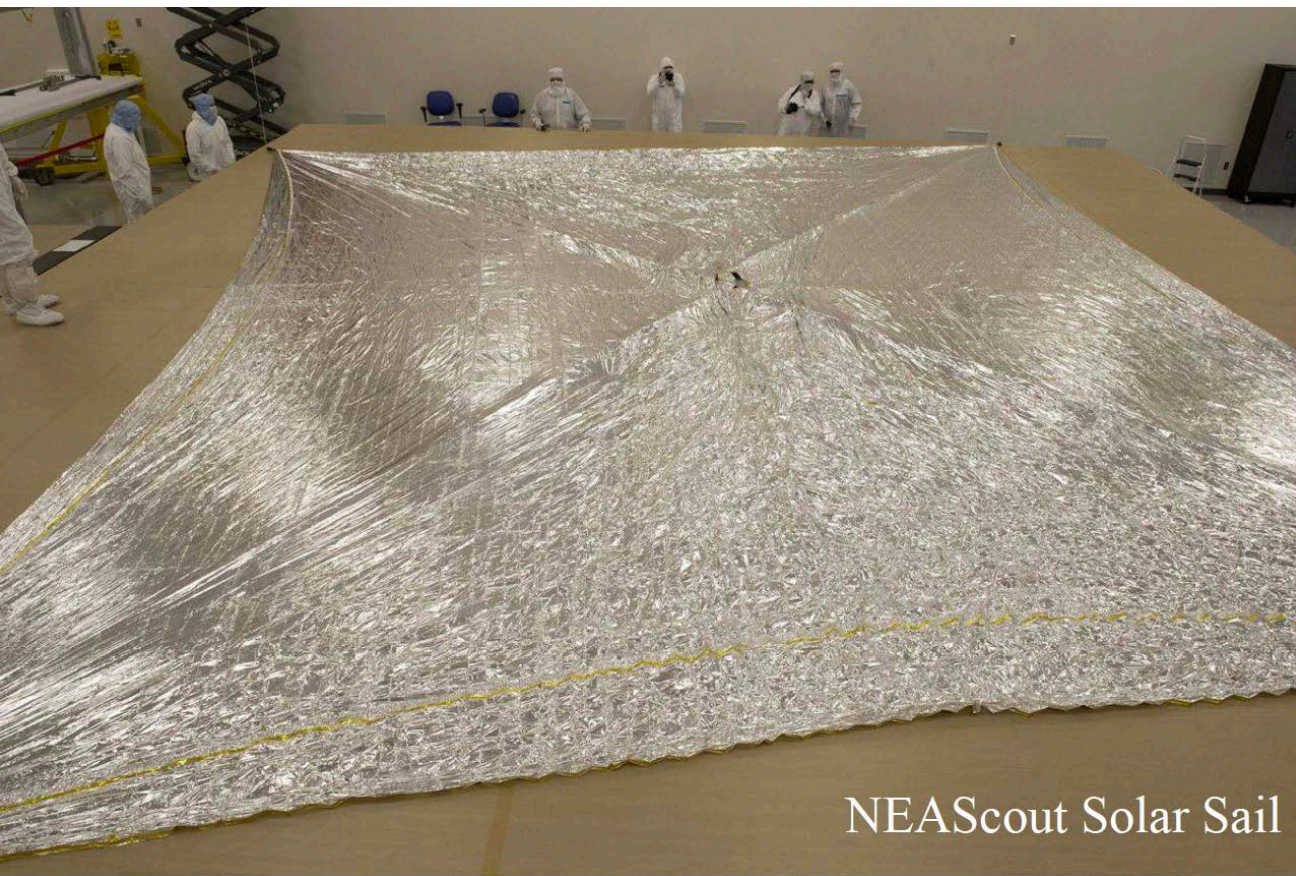
Imaging X-ray
Polarimetry
Explorer
(IXPE)

Understanding Our World and Beyond



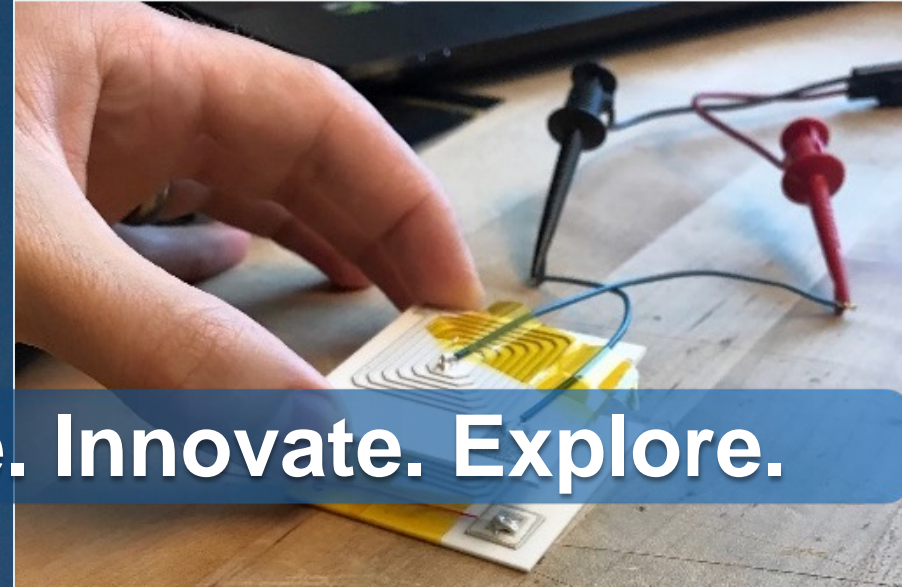
The Lightweight
Integrated Solar Array
and anTenna (LISA-T)





NEAScout Solar Sail





Inspire. Innovate. Explore.



nasamarshallcenter



@NASA_Marshall



@NASA_Marshall



NASAMarshallTV



nasamarshall

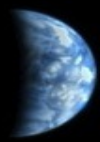
Electronics
Engineers:
Closes 3/14

[https://www.usajobs.gov/GetJob/
ViewDetails/525733000](https://www.usajobs.gov/GetJob/ViewDetails/525733000)

www.nasa.gov/marshall

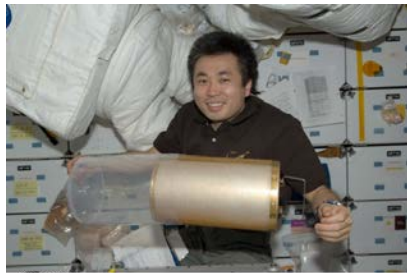
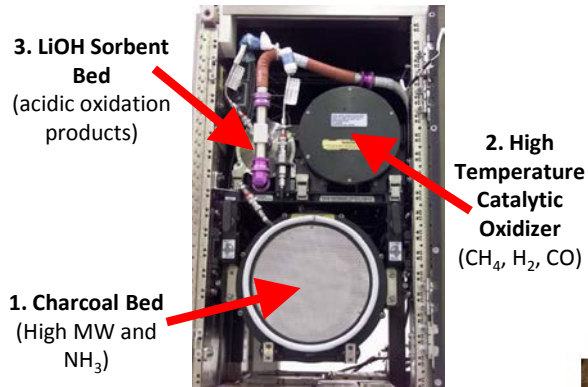
Back-Up Charts





Life Support Today: ARS Rack

Trace Contaminant Control



JAXA's Koichi Wakata with replaceable LiOH cartridge

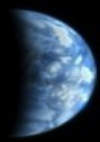
CO₂ Removal



5A Zeolite options for CDRA

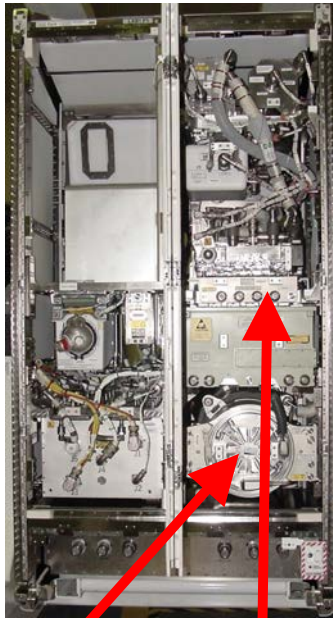


CDRA



Life Support Today: OGS Rack

Oxygen Generation Assembly



Cell Stack &
Rotary
Separator
Accumulator

Hydrogen
Sensor

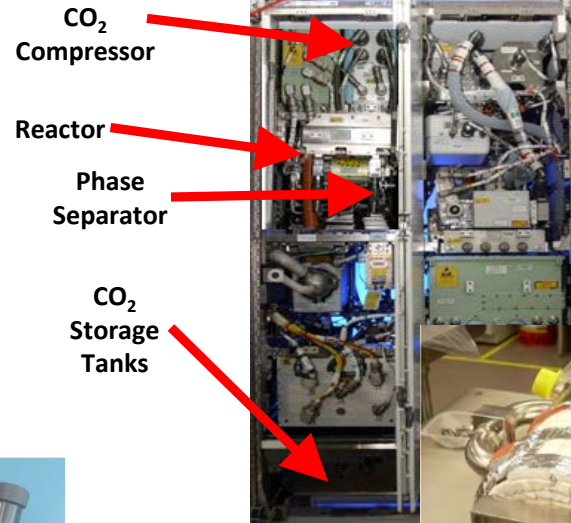


Hydrogen
ORU without
dome



H2 in O2 sensor
(150 day life)

Sabatier CO₂ Reduction

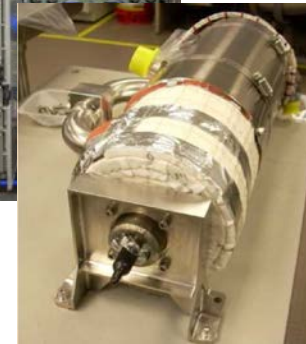


CO₂
Compressor

Reactor
Phase
Separator

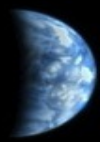
CO₂
Storage
Tanks

~50% O₂
Recovery



Flight Sabatier
Reactor





Life Support Today: WRS Racks

Urine Processing Assembly

Pumps

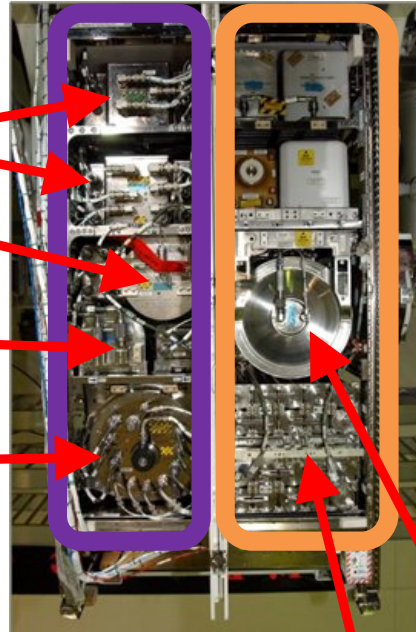
Brine Tank

Urine Storage Tank

Distillation Assembly

UPA = ~80%

H₂O
Recovery



Multi-filtration Beds

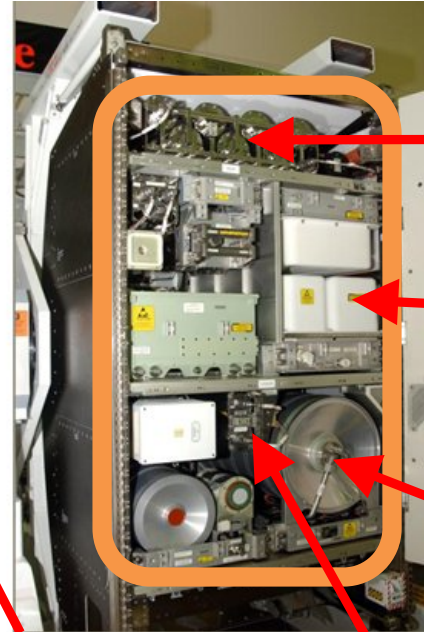
Combined ~88%
H₂O Recovery

Water Processing Assembly

Particulate Filter

Catalytic Oxidizer

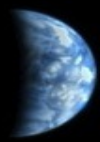
Product Water Tank



Wastewater Tank

WPA = >99%
H₂O
Recovery

Ion Exchange Bed



Life Support in the Past: Mercury and Gemini



Mercury Astronauts
1961-1963



Redstone Rocket
Launch (first two
flights)



Titan II Rocket



First Spacewalk
Gemini 4
Ed White 1965

- 1-2 astronauts
- 1-14 day missions
- Chlorinated potable water & O₂ stored in tanks
- CO₂ removed from atmosphere w/expendable LiOH
- Wastewater vented overboard





Life Support in the Past: Apollo



Command Module

- 7-10 day missions
- 3 crew
- Fuel cell by-product water used for drinking, chlorinated manually by crew
- Wastewater vented overboard
- O₂ stored in tanks
- CO₂ scrubbed w/ LiOH
- Rudimentary waste collection

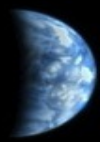


Saturn V Rocket



Lunar Module

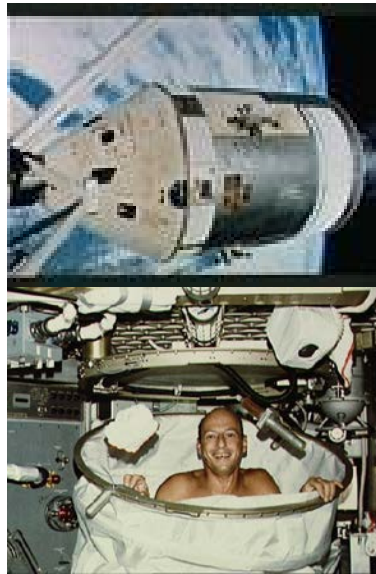
- 1-3 day missions
- 2 crew
- Iodinated potable water stored in tanks
- Wastewater stored in tanks
- Stored O₂
- CO₂ scrubbed w/ LiOH



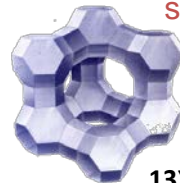
Life Support in the Past: Skylab



1973-1979

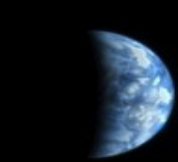


Skylab CO₂ Scrubber



13X Zeolite

- 3 missions (28, 59, & 84 days)
- 3 crew
- Potable water provided for consumption & hygiene in tanks
- Iodinated potable water stored in tanks (10 x 70-gal tanks)
 - periodic iodine injections by crew
 - manual colorimetric checks
- Wastewater vented overboard
- Stored O₂
- CO₂ scrubbed w/ molecular sieve (13X and 5A) and vented overboard
- Trace contaminant control using a charcoal bed
- Hygiene Facilities including toilet and shower



Life Support in the Past: Space Shuttle



- 7-16 day missions typical
- 6-7 crew typical
- Fuel cell by-product water used for potable water
- Iodine added automatically via flow-thru iodinated resin
- Wastewater vented overboard
 CO_2 scrubbed w/ LiOH
- Stored (cryo) O_2

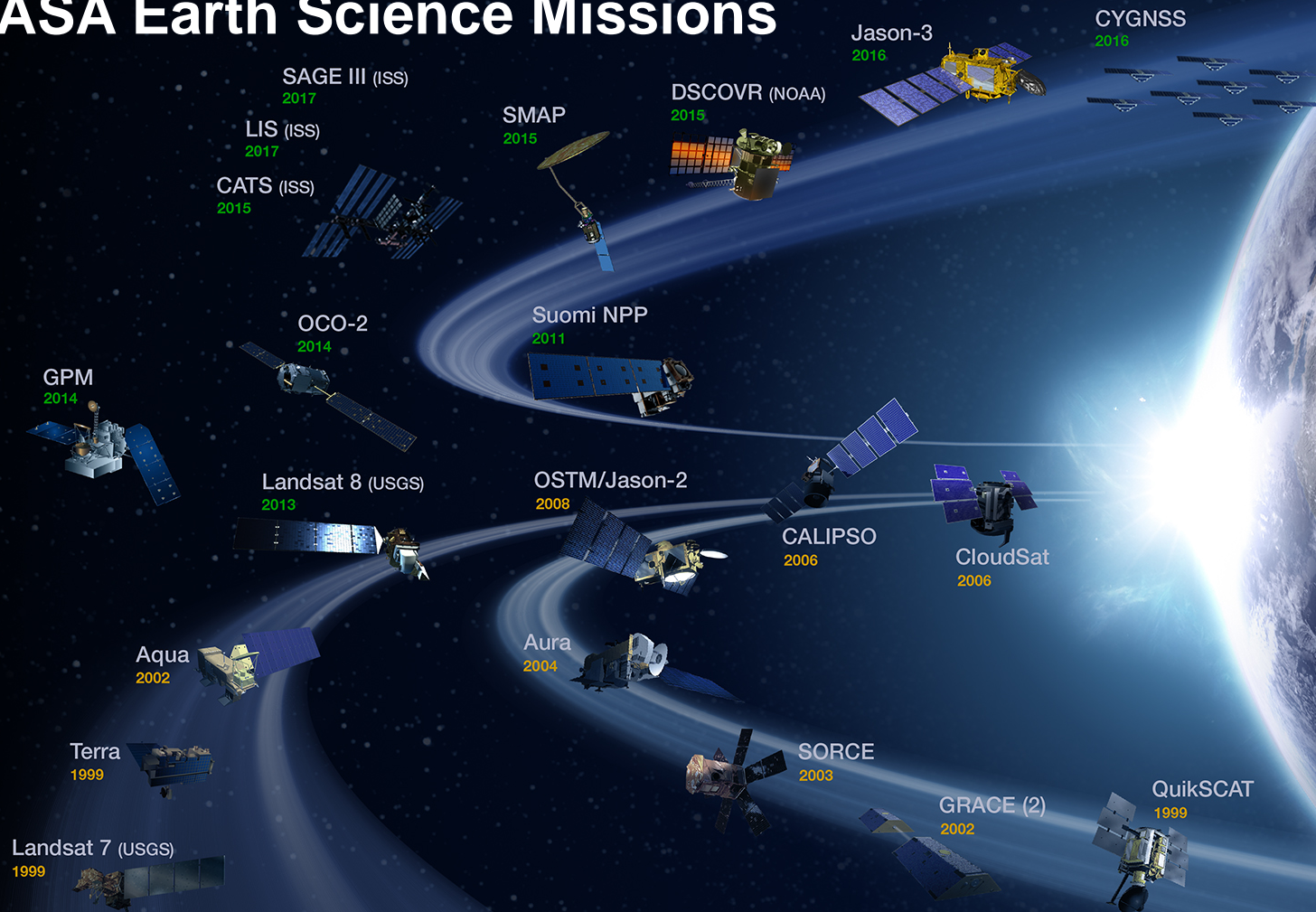


595E5055 1998:10:30 10:42:55



Understanding Our Home Planet

NASA Earth Science Missions



SERVIR connects space to village by helping developing countries use satellite data to address critical challenges in food security, water resources, weather and climate, land use, and natural disasters. A partnership of NASA, USAID, and leading technical organizations, SERVIR develops innovative solutions to improve livelihoods and foster self-reliance in Asia, Africa, and the Americas.



Agriculture & Food
Security



Water & Water-
Related
Disasters



Land Cover &
Ecosystems



Weather & Climate

SERVIR 

 **USAID**
FROM THE AMERICAN PEOPLE



adpc

ICIMOD

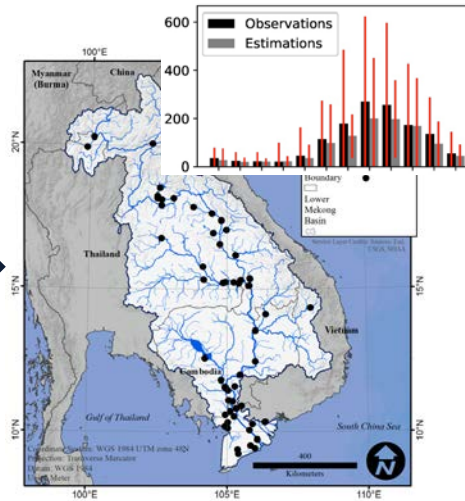
 **CIAT**





Dam on Nam Theun river in Laos

New dam construction and changes in land cover and land use is having a significant impact on sediment loads and water quality throughout the Lower Mekong basin.



Limited *in situ* sediment measurements sites used to compute model accuracy

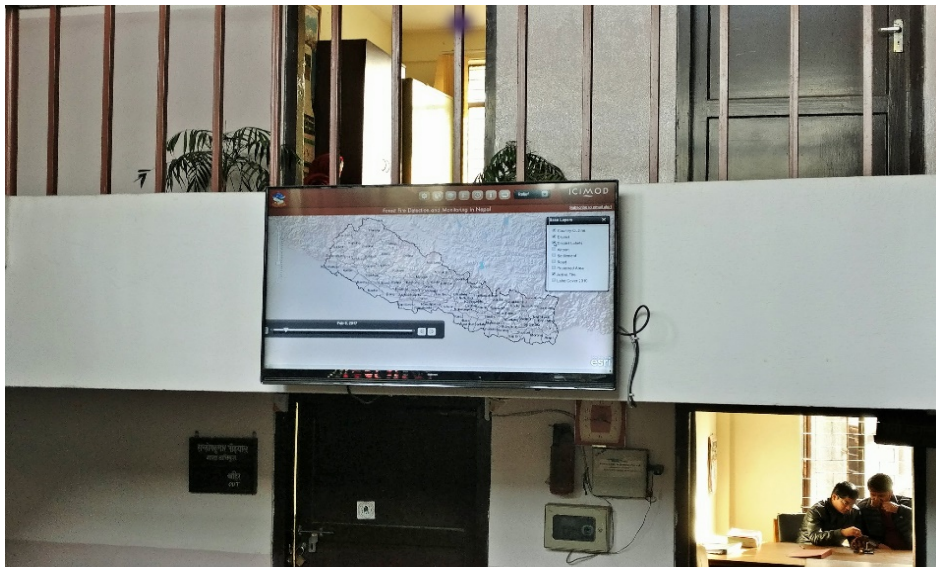
Previously, to assess sediment concentration, decision makers had to rely on their sparse network of *in situ* water quality stations in the Mekong River Basin.



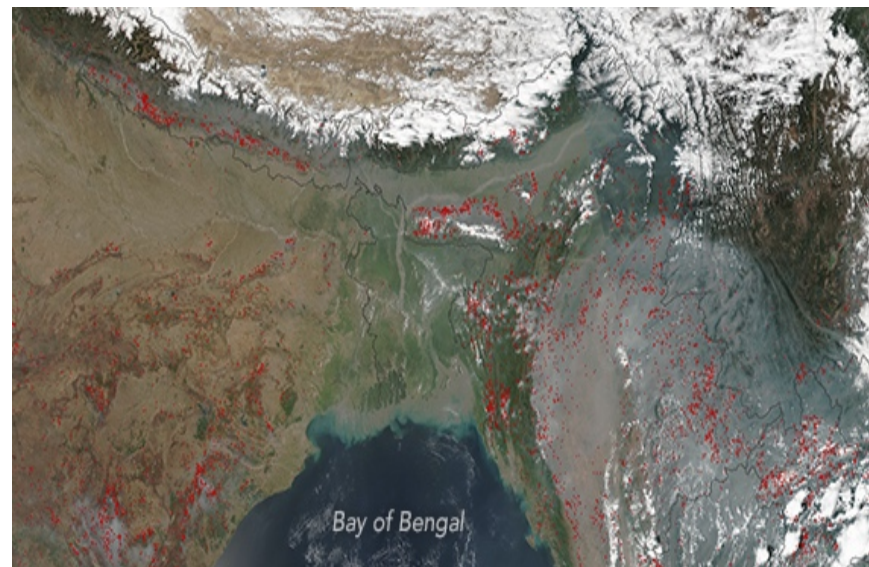
SERVIR's work was featured on the front page of the June issue of Remote Sensing

SERVIR and the Mekong River Commission implemented a model leveraging the entire Landsat archive, allowing users to supplement limited station data with satellite products. The model output enables dam managers to reduce the impact of sedimentation on fisheries downstream.

Monitoring Sedimentation In the Mekong River



SERVIR's Forest Fire Monitoring System displayed in Nepal government lobbies



Red dots indicate forest fire hot spots, as detected by the satellite thermal sensors

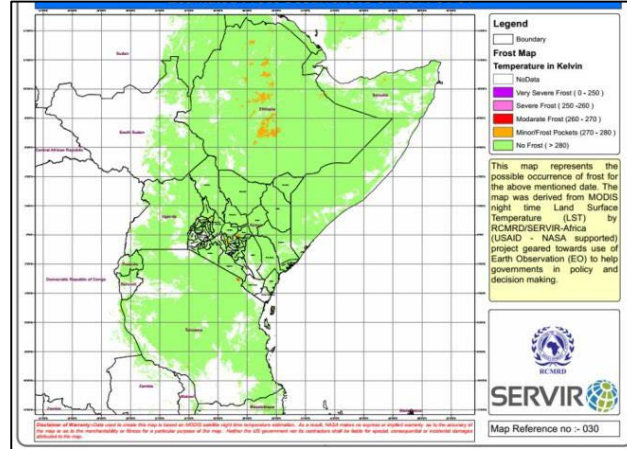
Through SERVIR's fire monitoring system, use of satellite data is firmly embedded in Nepal's government Forest Department. This system triggers action and response on the ground, especially in remote areas of the country.

Detecting and Responding to Forest Fires in Nepal

SERVIR's satellite-based monitoring and forecasting of frost conditions in the Kenyan tea growing regions has spurred insurance companies to offer new, frost insurance riders to farmers. The satellite data has been used to adjudicate insurance claims and provides great opportunities for taking preventive actions, such as harvesting the tea leaves before a frost. This information is relayed to the farmers at local collection points.



SERVIR team meeting with Kenyan tea farmers to understand possible mitigation options based on frost forecasting information



SERVIR frost occurrence map showing affected areas in Kenya (orange areas)



Tea leaves affected by frost

Forecasting and Mapping Frost for Kenyan Tea Farms



SERVIR

SERVIR connects space to village by making geospatial information useful to developing countries.

SERVIR is a joint development initiative of NASA and USAID, working in partnership with leading regional organizations around the globe.

EXPANDING AROUND THE GLOBE

47

countries directly served by SERVIR products, applications, or trainings

27

satellites and sensor data used by SERVIR

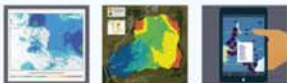
62

countries benefiting from SERVIR cooperation

PRODUCTS, TOOLS, AND SERVICES

88

climate change adaptation and mitigation products developed



1.5M

maps produced interactively on the SERVIR web portal



By the Numbers Thru:
2017

www.servirglobal.net

TRAINING AND INFORMATION SHARING

4719



people trained to use tools and information

353



institutions worldwide with improved capacity to address climate change issues

647



decision-makers and scientists participating in technical exchanges

CONNECTING MORE SCIENCE

28

United States Government science expertise connections (2017)



25

SERVIR Applied Sciences Team projects (2017)



What and Who is SERVIR?

“Connecting space to village”

A joint initiative of USAID and NASA that partners with regional technical institutions around the world to get Earth observation information into the hands of decision-makers to improve development outcomes.



- Societal benefit from space
- 20+ satellites, data free and open
- Major research portfolio
- Limited internationally

Regional hubs



USAID
FROM THE AMERICAN PEOPLE

- Poverty reduction and resilience
- Working on data-dependent issues in data-scarce places
- International field presence

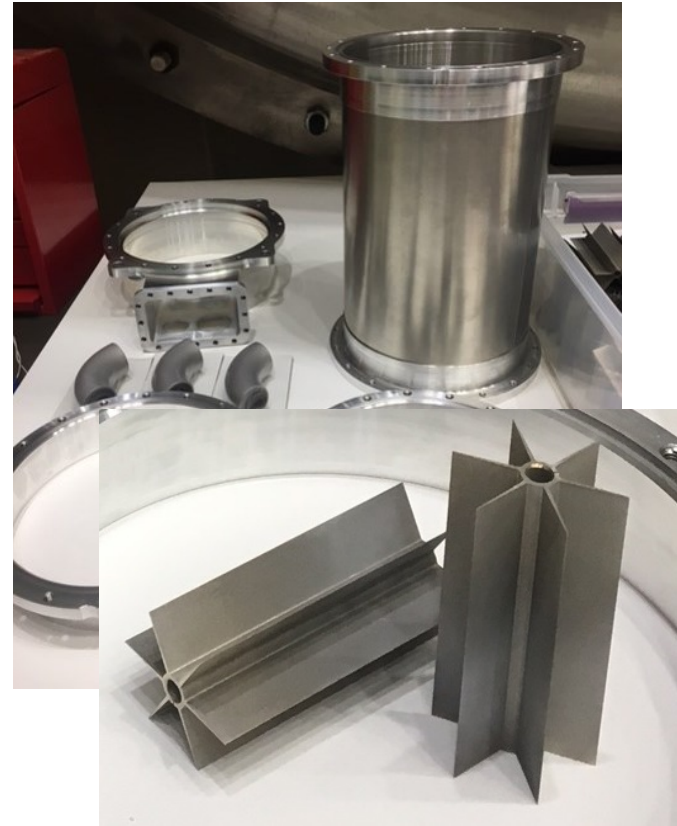
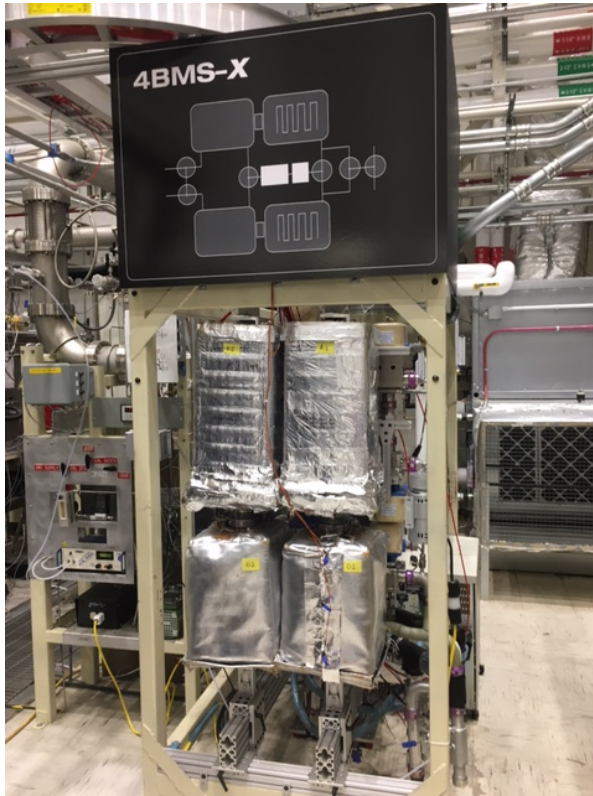
Hub partners



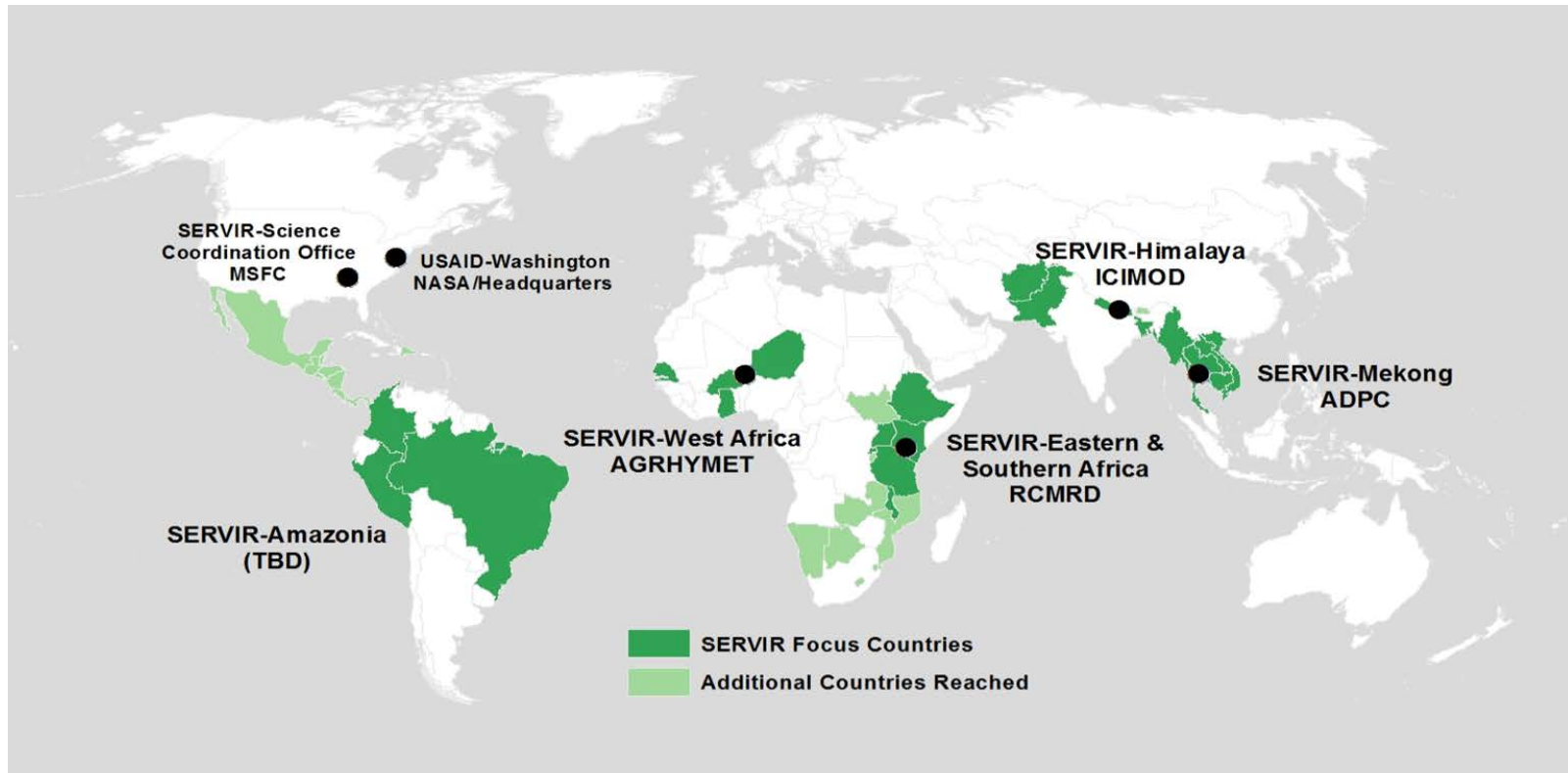
Private sector partners: Google  esri  DigitalGlobe  aws 

Research collaborators:

19 universities and research centers located in 14 states (in the U.S.)



4BMS-X: CO₂ Removal Tech Demo

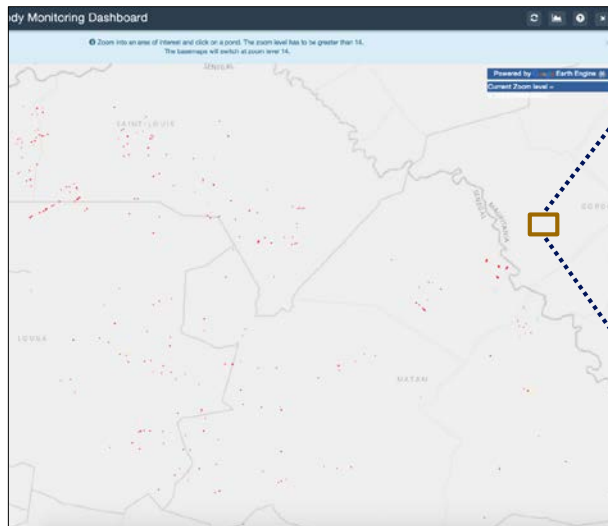


Working in Over 40 Countries

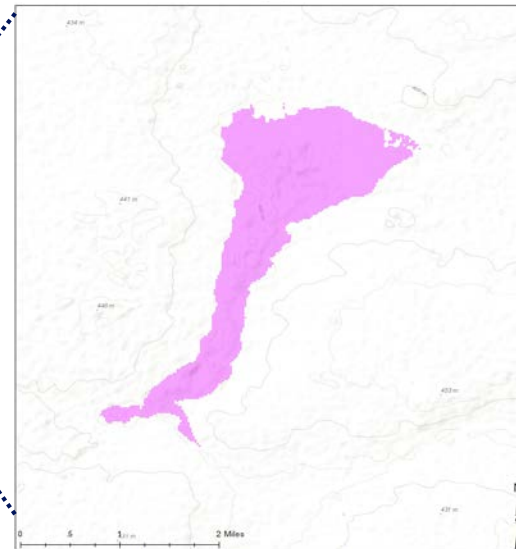
Pastoralists in parched West African rangelands are always in search of ponds with water for their livestock. SERVIR has developed a tool that scans the latest satellite data and updates a map of available water in those ponds. This information is relayed to the pastoralists by radio and cellphones.



Pastoralists in West Africa searching for water and forage.



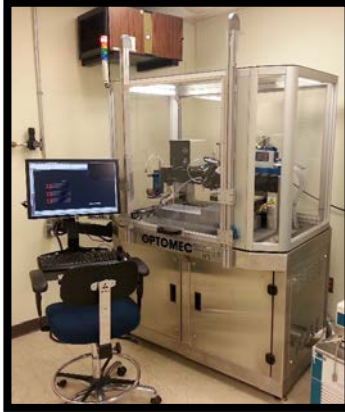
Using latest satellite observations, SERVIR monitors thousands of small ephemeral ponds across the Senegal to determine the availability of water



Monitoring changes in pond water over time

Monitoring Small Water Bodies in West Africa for Pastoralists

**Optomec High Precision
3D Aerosol Jet Printer**



Additive Electronics Manufacturing

Primary Focus: Utilizing 3D additive dispensing, screen printing, and aerosol jet deposition processes to develop nanoelectronics including but not limited to:

- **Solid State Ultracapacitors**
- **Graphene Superconducting Circuitry**
- **Organic Photovoltaics & LEDs**
- **Electroluminescent Devices**
- **Sensors**
- **PCBs**
- **Antennas**
- **3D Flexible Interconnects for Area Array Packaging**
- **Embedded Electronics Packaging**
- **Advanced Electronic Manufacturing**

**HMI 485 High Precision
Screen & Stencil Printer**



**Hengli Custom 8-Zone HT
Sintering Furnace**



**Hengli Custom 4-Zone LT
Sintering Furnace**



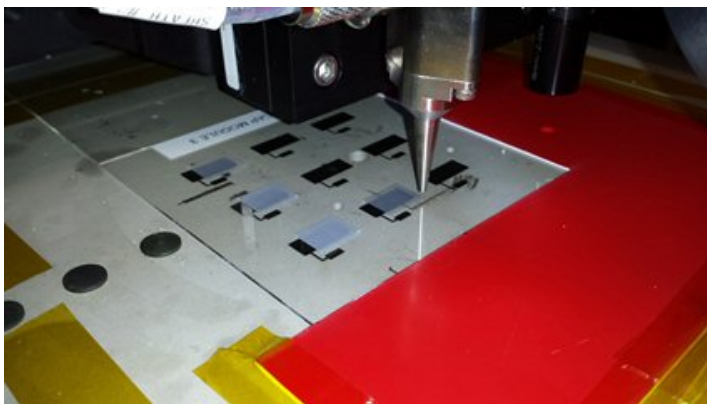
**Silverson L5M-A
Laboratory Mixer**



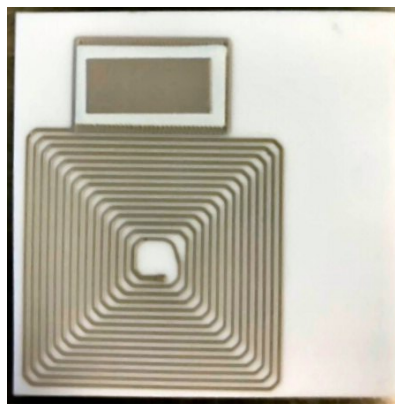
**PVA 350 Tabletop
Robotic Dispensing System**



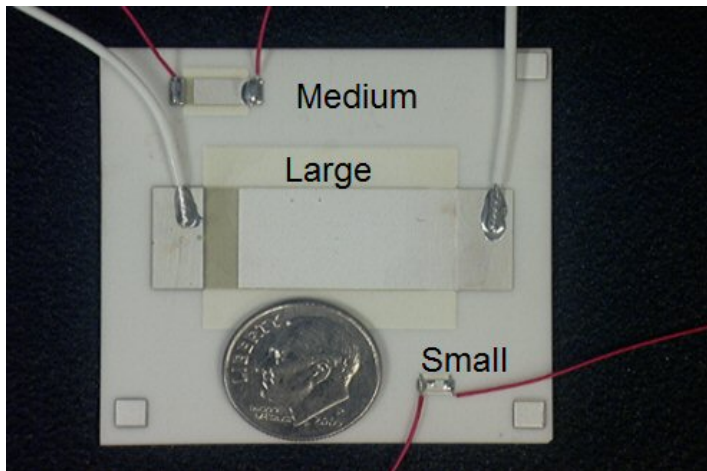
EEE Parts Packaging- Additive Electronics Laboratory



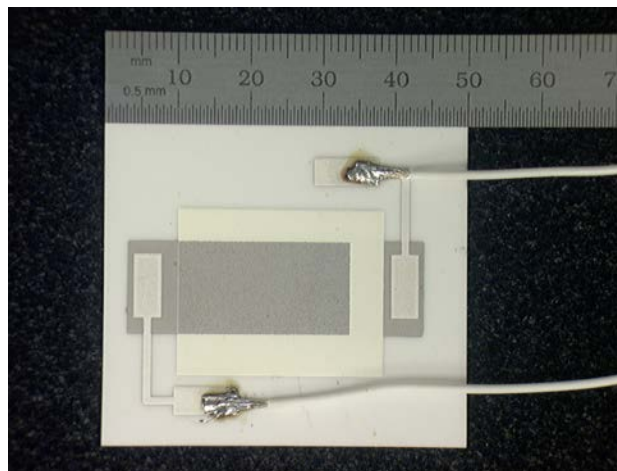
Dielectric ink printing



Wireless humidity sensor



Three different sizes



Ultra cap with leads



[POWER SAIL]

BOL | 28°C | 30% IMM

0.6m² (herein)

-- 200W 1AU | 86W Mars

2.9m² (office desk)

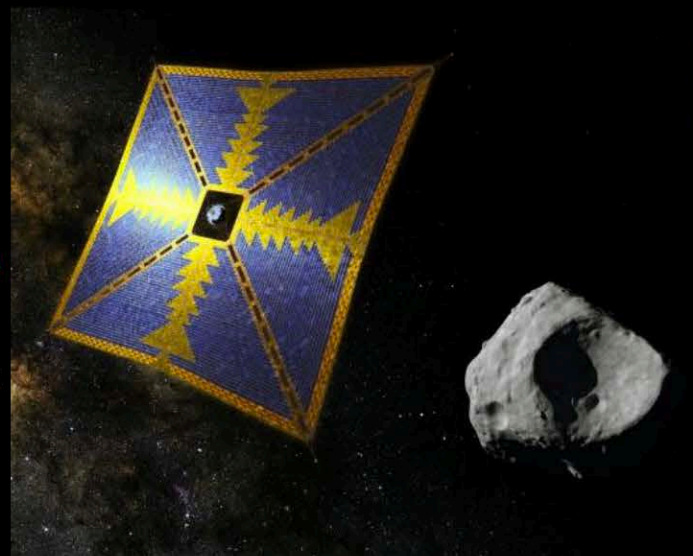
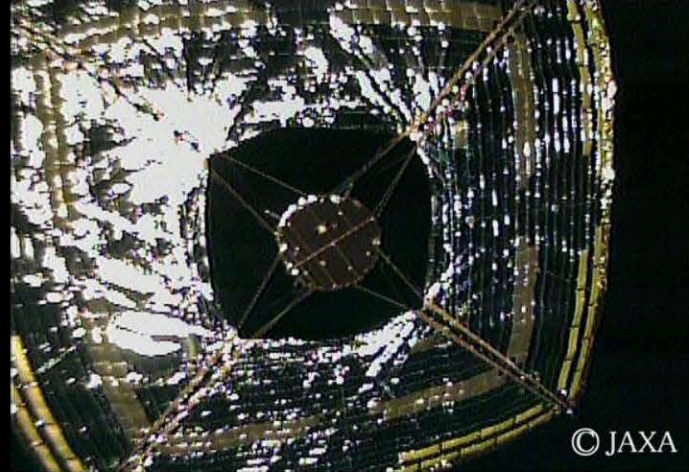
-- 1kW 1AU | 431W Mars

86m² (NeaScout)

-- 23kW 1AU | 250W Saturn

860m² (3.3 tennis courts)

-- 300kW 1AU | 192W Pluto



A person in a camouflage jacket and pants stands on a dark, rocky shore, holding a long wooden paddle. Two black dogs sit beside them, looking out over a calm lake. In the background, a dense line of trees is illuminated by a warm, golden light, likely from a setting or rising sun. The sky is overcast and grey. The word "Reflections" is written in white text on the right side of the image.

Reflections