National Aeronautics and Space Administration

IA012 NASA Fuel Cell and Hydrogen Activities

Department of Energy
Annual Merit Review
Interagency Track

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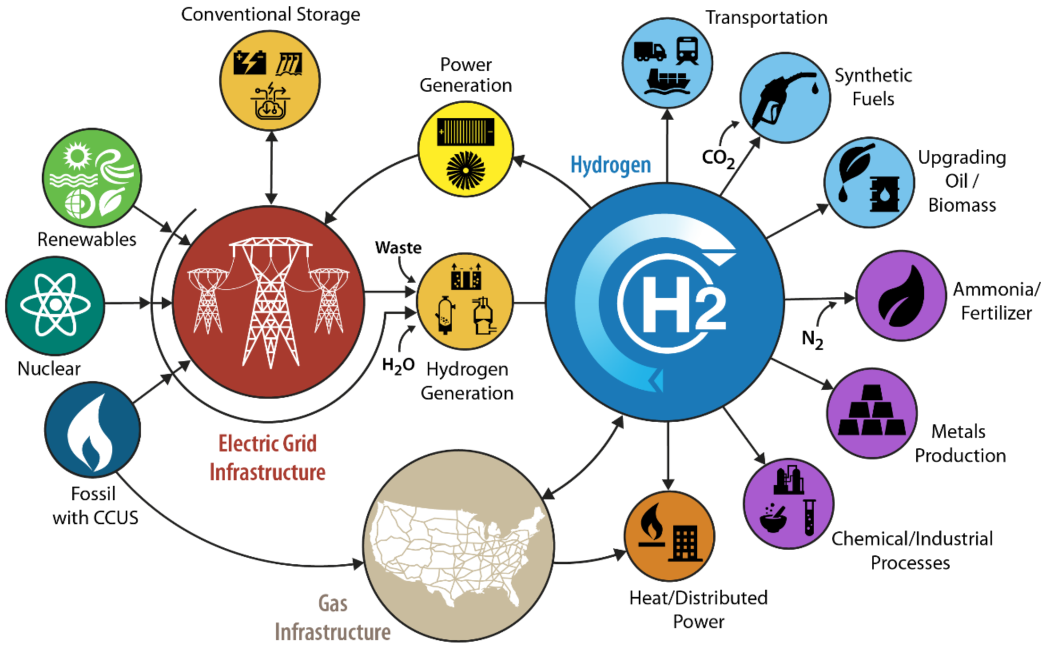
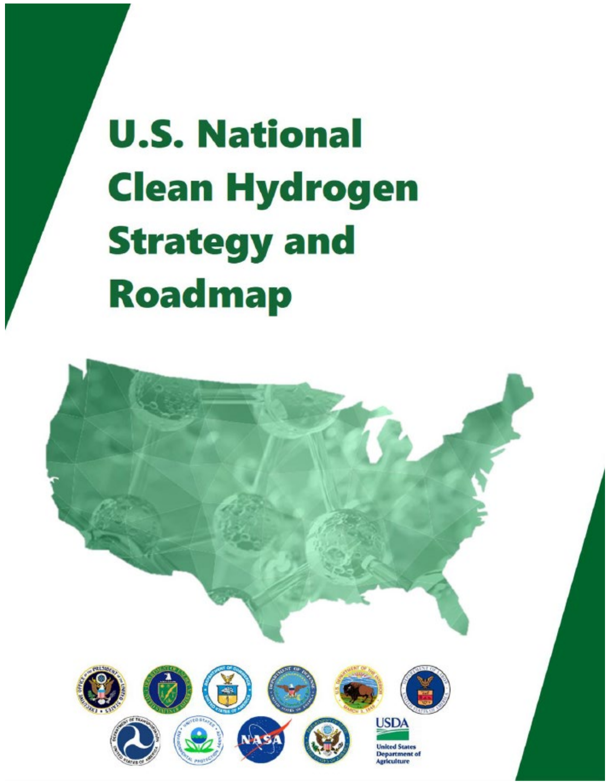
8 May 2024

U.S. National Clean Hydrogen Strategy and Roadmap

- U.S. National Clean Hydrogen Strategy and Roadmap outlines the Administration's plan to implement the Carbon-reduction activities outlined in the Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act (IRA) https://www.hydrogen.energy.gov/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf
- Department of Energy (DOE) leads an "all-of-government" Hydrogen Interagency Taskforce (HIT) to guide the implementation of the Hydrogen Strategy and Roadmap https://www.hydrogen.energy.gov/interagency.html

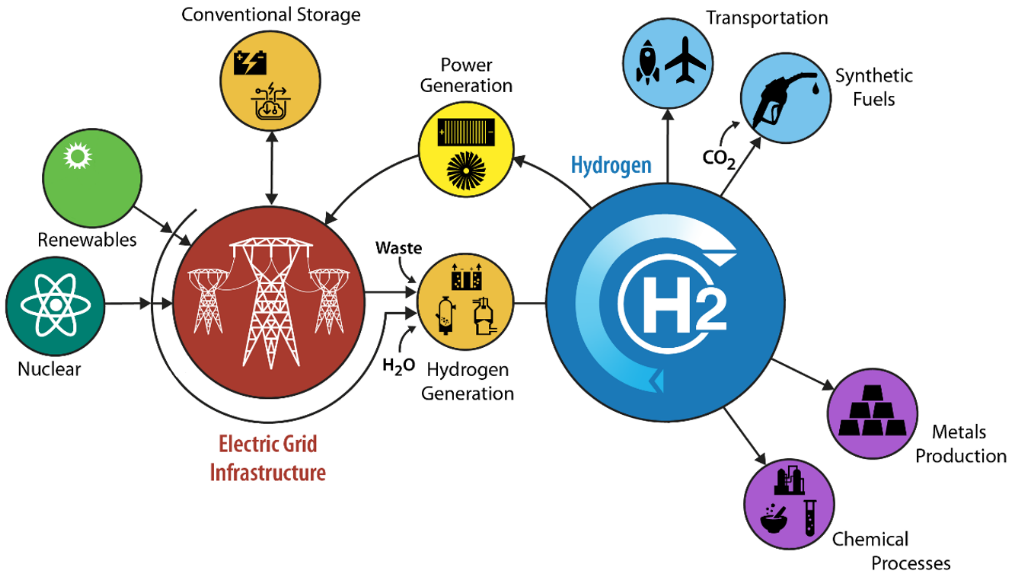


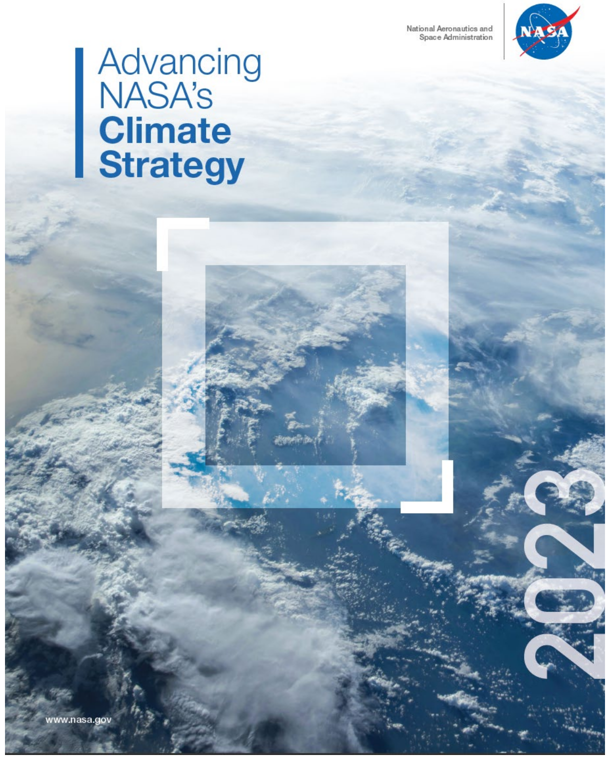


NASA Climate and Space Sustainability Strategies

- NASA actively participates in the DOE Hydrogen Interagency Taskforce (HIT)
  - Supports all Working Groups and some Cross-cutting Teams
  - Hydrogen Training available to participating HIT agencies
- DOE HIT activities align with NASA Climate Strategy released last year

  https://www.nasa.gov/wp-content/uploads/2023/04/advancing-nasas-climate-strategy-2023.pdf





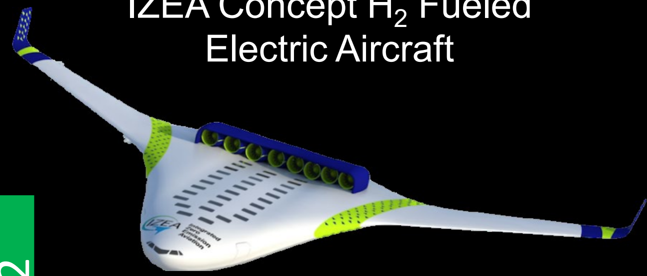
Fuel Cell and Hydrogen Applications Within NASA

LH2 Tank at Pad 39B

Energy Storage

Long-term storage and management of H_2, O_2 and water

IZEA Concept H_2 Fueled Electric Aircraft



O_2 H_2

On the Ground
In the Air
In Space

H_2 O_2

Water Electrolysis

Generate H_2 and O_2 from water

H_2O

Power Generation

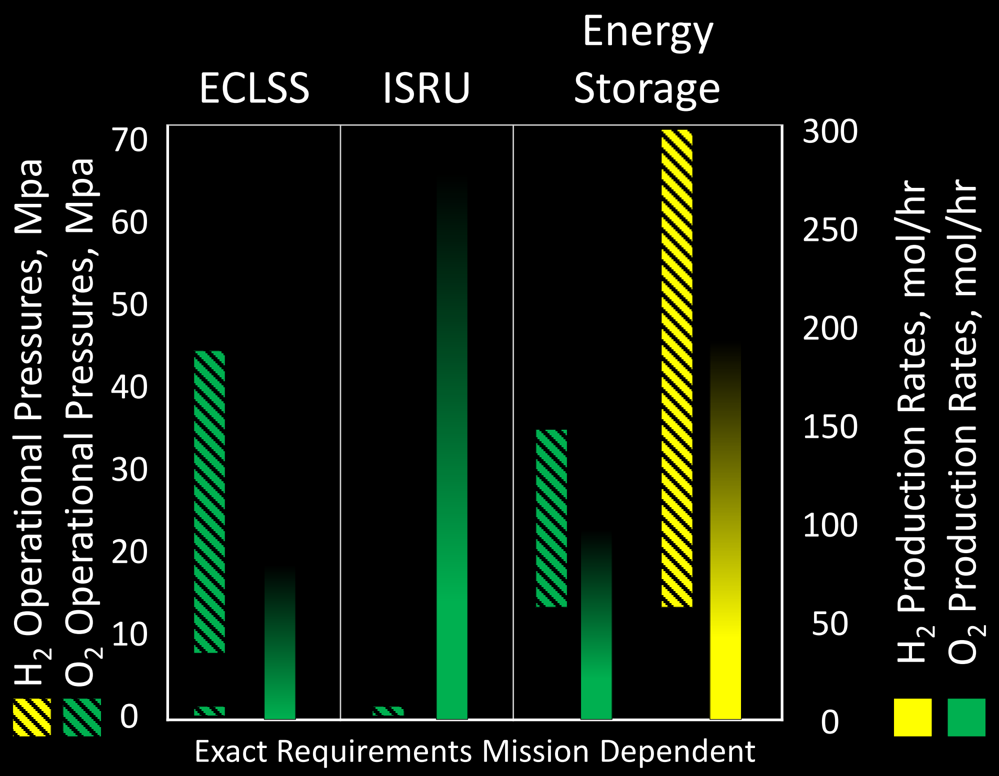
- *Electrochemically combine H_2 and O_2 into H_2O, heat, & electricity*
- *Combust H_2 to generate thrust*

Water Electrolysis

H2 and O2 Reactant Generation

- *Electrochemically dissociate water into gaseous H_2 and O_2*
  - *Balanced and Unbalanced designs*
  - *Low Pressure (< 0.3 MPa, < 45 psia)*
  - *Medium Pressure (<1.7 MPa, < 250 psia)*
  - *High Pressure (> 10 MPa, > 1,500 psia)*
  - *Contaminated Water Sources for ISRU*
- *ECLSS*
  - *Unbalanced Design ($H_2 << O_2$)*
  - *Unmet long-term requirements for reliability, life, or H_2 sensors stability*
- *Energy Storage*
  - *Balance Design ($H_2 \approx O_2$)*
  - *Unmet long-term requirements for performance, reliability, life, sensors availability, sensor stability*
- *In-situ Resource Utilization (ISRU)*
  - *Balance Design ($H_2 \approx O_2$)*
  - *Unmet long-term requirements for performance, reliability, or life*
  - *Tolerate contaminated water sources to minimize pre-conditioning requirements*

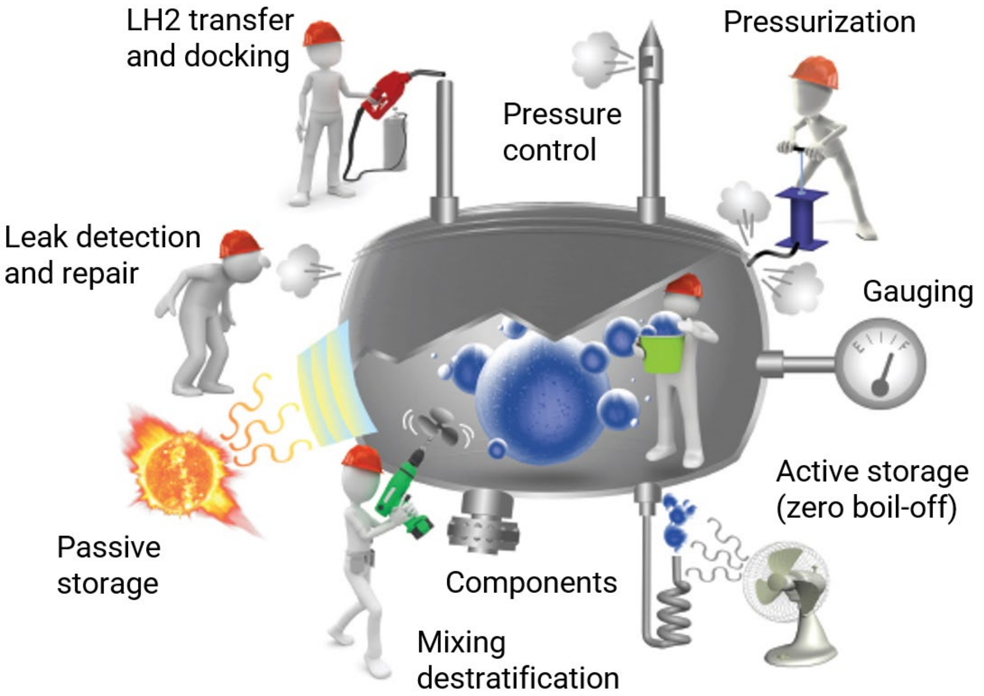
Notional Electrolysis Requirements



All applications Power and Mass Constrained

Energy Storage

- NASA stores Hydrogen as compressed gas, cryo-compressed fluid, and cryogenic liquid
- NASA participates in developing and maintaining industry Codes and Standards
- Systems safely provide fuel to user systems at desired pressure, temperature, and flow rates through multiple system operational modes and mitigate potential failures



800,000 gal (3,3028 m^3)
LH2 Tank at Pad 39B
(NASA Image KSC-20191108-PH-JBS01_0001)

Tanker trucks deliver liquid hydrogen (LH2) to replenish the large sphere at NASA's Kennedy Space Center in Florida, Launch Pad 39B.
(NASA Image NHQ202208310013)

Fuel Cell Power Generation

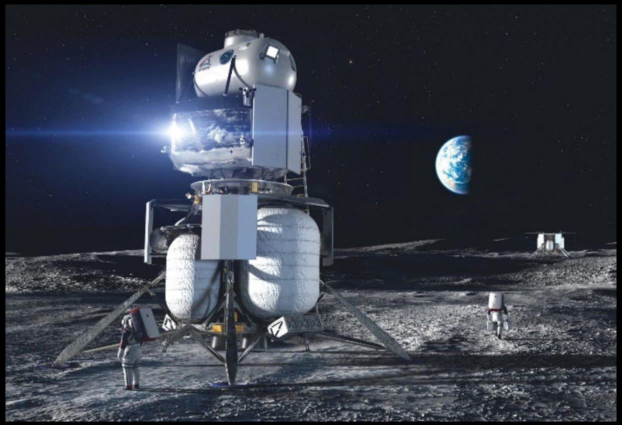
Fuel cells provide primary direct current (DC) electrical power

- *Use pure to propellant-grade O_2 / H_2 or O_2 / CH_4 reactants*
- *Uncrewed experiment platforms*
- *Crewed/uncrewed rovers*
- *Electric aircraft / Urban Air Mobility (UAM)*

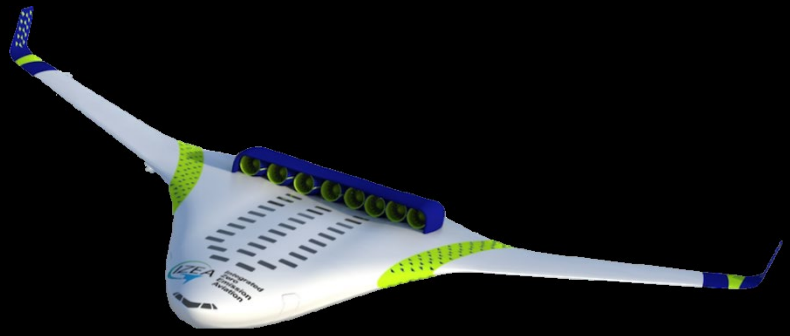
Center for High-Efficiency Electrical Technologies for Aircraft (CHEETA)
Design Study for Hydrogen Fuel Cell Powered Electric Aircraft using Cryogenic Hydrogen Storage

Applications

- *Electric Aircraft / Urban Air Mobility: 120 kW to > 20 MW*
- *Lunar / Mars Landers: ~ 2 kW to ≤ 10 kW*
- *Lunar / Mars surface systems: ~ 2 kW to ≤ 10 kW modules*



Blue Origin Lunar Lander Baselined Fuel Cell Power as primary power source

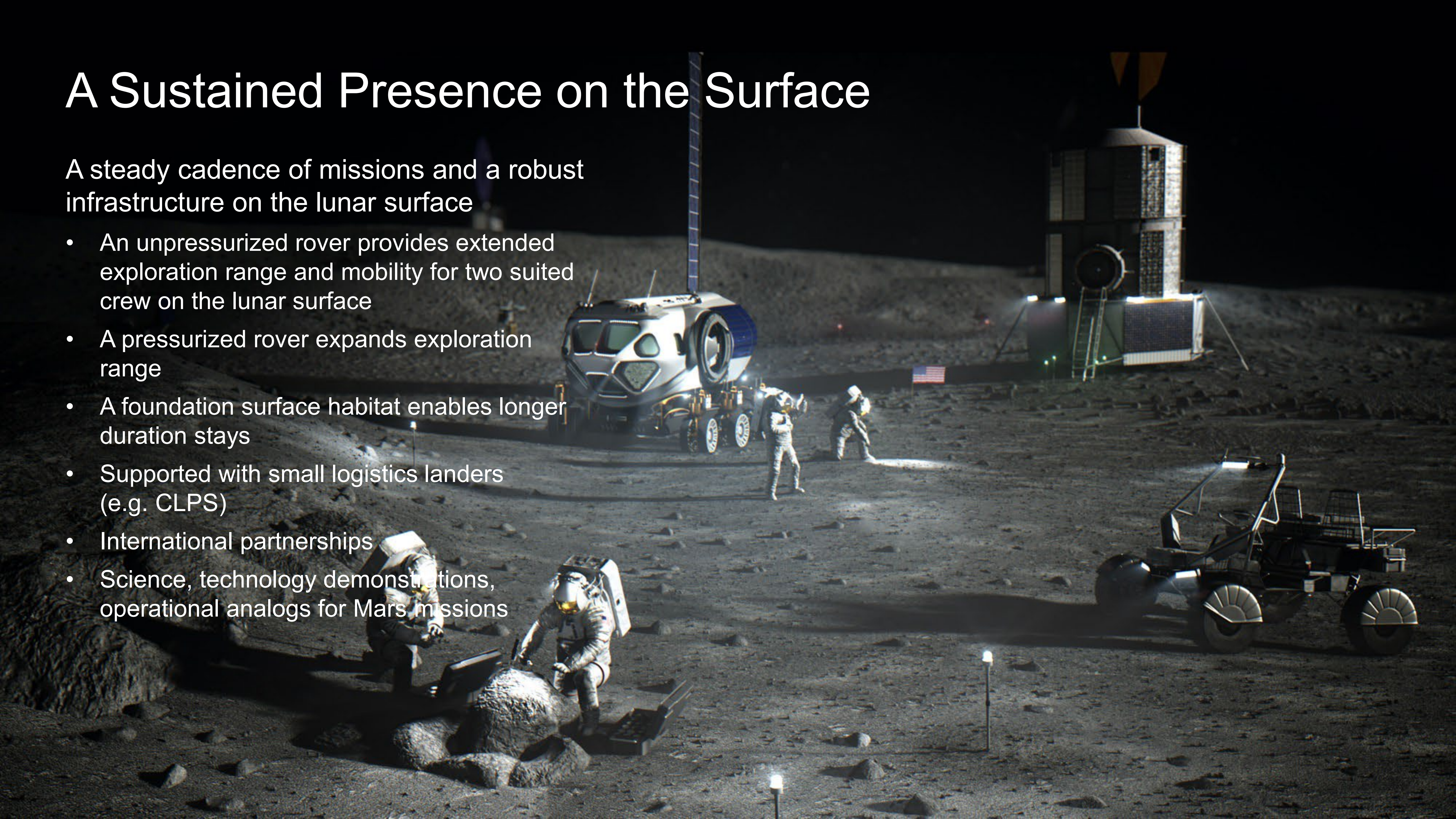


Concept H_2-fueled Aircraft for the Integrated Zero Emission Aviation (IZEA) ULI activity led by the University of Kentucky

ARMD and Hydrogen-Related Investment

- ARMD invests broadly in technologies for a sustainable aviation future. The use of hydrogen as an aviation fuel through direct burn combustion or fuel cell-electric application is being explored at a low level amongst other options; there is no directed funding for hydrogen-specific technology development, and such ideas compete with other alternatives. *Current investment $7-8M/year, mostly to university-led teams.*

- Transformative Aeronautics Concepts Program (TACP)
  - University Leadership Initiative: These recipient defined efforts total approximately $7M/year in FY2024 and FY2025
    - **University of Illinois:** CHEETA - Develop cryogenic & hydrogen technologies for a hydrogen aircraft
    - **University of Central Florida:** ALFA - Technologies for using ammonia for a hydrogen powered aircraft
    - **Florida State University**: IZEA - Hydrogen powered hybrid electric power system that uses turboelectric generators and fuel cells
    - **Tennessee Technological University:** CLEAN - Integrated propulsion, power, and thermal management system for an ammonia-based aircraft
  - Transformational Tools and Technologies Project
    - **Exploration of Hydrogen-based Concepts**: $0.5M per year in FY2024 and FY2025
- Advanced Air Vehicles Program (AAVP)
  - Approximately $100k (internal labor) effort on H2 aircraft design exploration (AATT/SA&I)
  - AACES 2050 advanced concepts solicitation (currently in proposal evaluation phase)
    - Hydrogen-based research within scope, but not a requirement nor pre-determined selection – investment is TBD
- Integrated Aviation Systems Program (IASP) & Airspace Operations and Safety Program (AOSP)
  - None
- No specific investments in aeronautical facilities related to hydrogen at this time.
- NASA ARMD and DoE leadership have periodic engagement on collaboration and monitor future opportunities



A Sustained Presence on the Surface

A steady cadence of missions and a robust infrastructure on the lunar surface

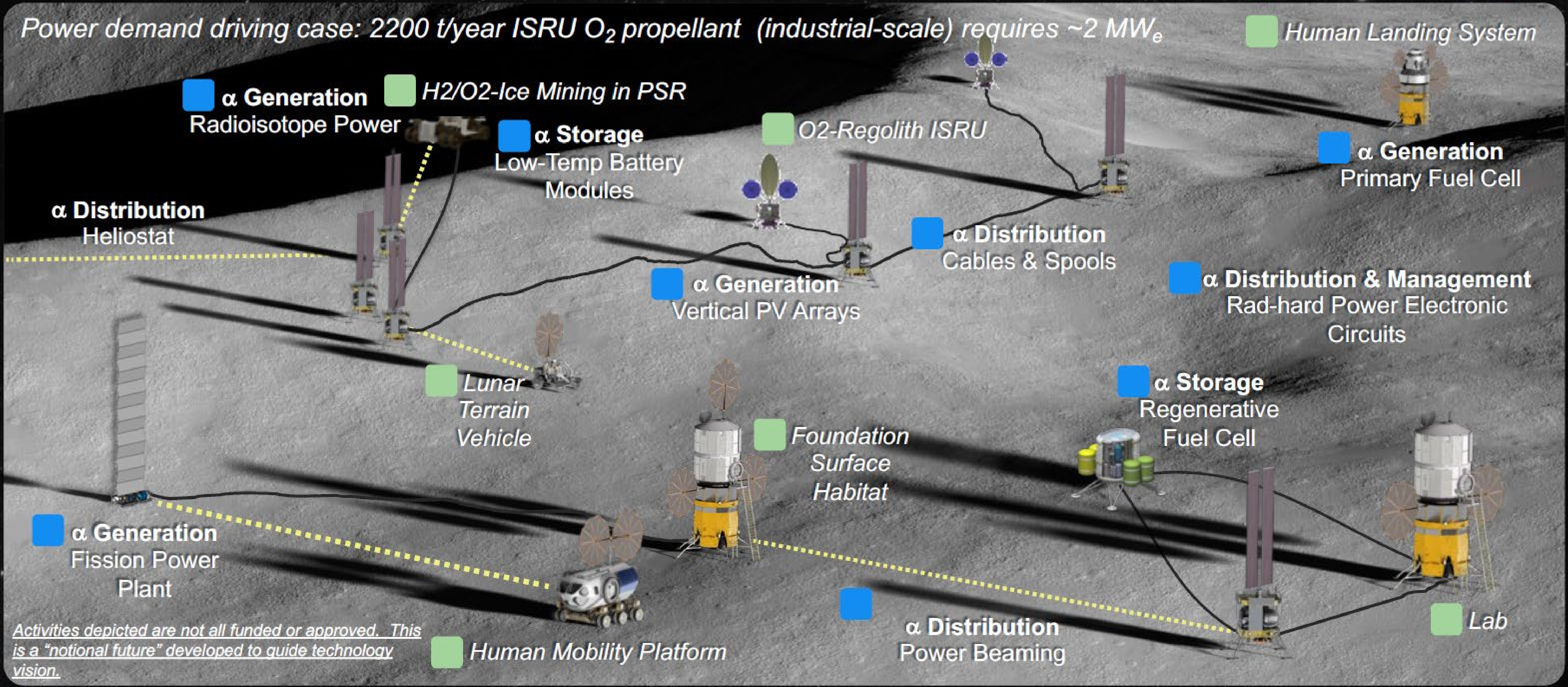
- An unpressurized rover provides extended exploration range and mobility for two suited crew on the lunar surface
- A pressurized rover expands exploration range
- A foundation surface habitat enables longer duration stays
- Supported with small logistics landers (e.g. CLPS)
- International partnerships
- Science, technology demonstrations, operational analogs for Mars missions

Power Architecture Building Blocks

Phase α South Pole Facilities: Handoff from Artemis Base Camp to Industry (~2030+)

Power system

Load



Activities depicted are not all funded or approved. This is a "notional future" developed to guide technology vision.

NASA TechPort

Website for the public to find:

- Latest Space Technology News
- Potential collaboration partners
- Funding opportunities / Solicitation announcements

https://techport.nasa.gov/dashboards

Questions?

Thank you for your attention.