Sierra Nevada Space Systems, Propulsion and Environmental Systems

SNC/SSG/RBI Overview

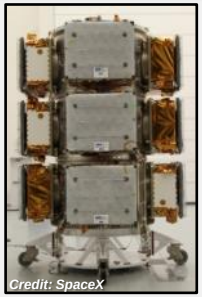
Thomas Crabb

Sierra Nevada Corporation's Space Systems

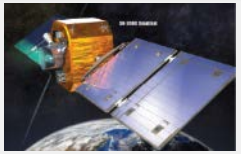
- ***26 Years*** **of Space Flight Heritage**
- **430+ Space Missions Supported**
- **4,000 Products Delivered On-Orbit**
- **Launching ~Every 3 Weeks**
- **Four viable business units**
- **Over 40 clients**
- **Over 30 strategic partners**
- **70+ Successful NASA Missions Flagship Space Programs**
- **Relationships in over 20 countries**
- **Over 500 people and growing**

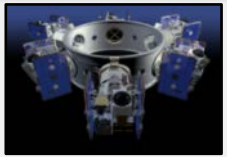
Space Systems Product Offerings

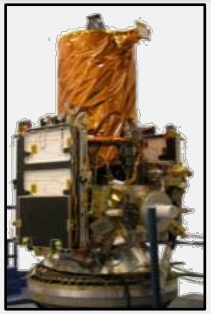
Spacecraft Systems

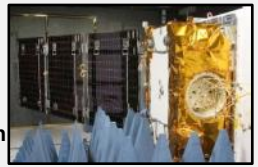


Constellation Mission Design and Satellite Production


Small Geo Satellites


ESPA Compatible

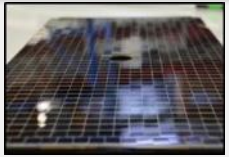

Earth Observation

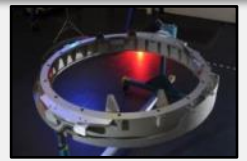

RF Applications


Near Space Systems

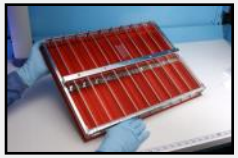
Space Technologies


Pointing & Motion Control


Electrical Power Systems


Berthing & Docking


Adapters & Separation Systems


Thermal Control

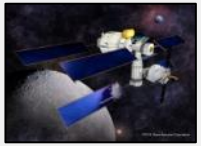
Electro-Mechanical

Space Exploration Systems

Dream Chaser® Space Utility Vehicle

NASA Commercial Cargo

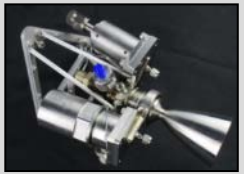
Crewed Missions


Deep Space Habitat

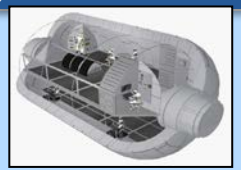
Science, Servicing, Remote Sensing, Exploration Support


Recovery System Upper Stages/Payloads

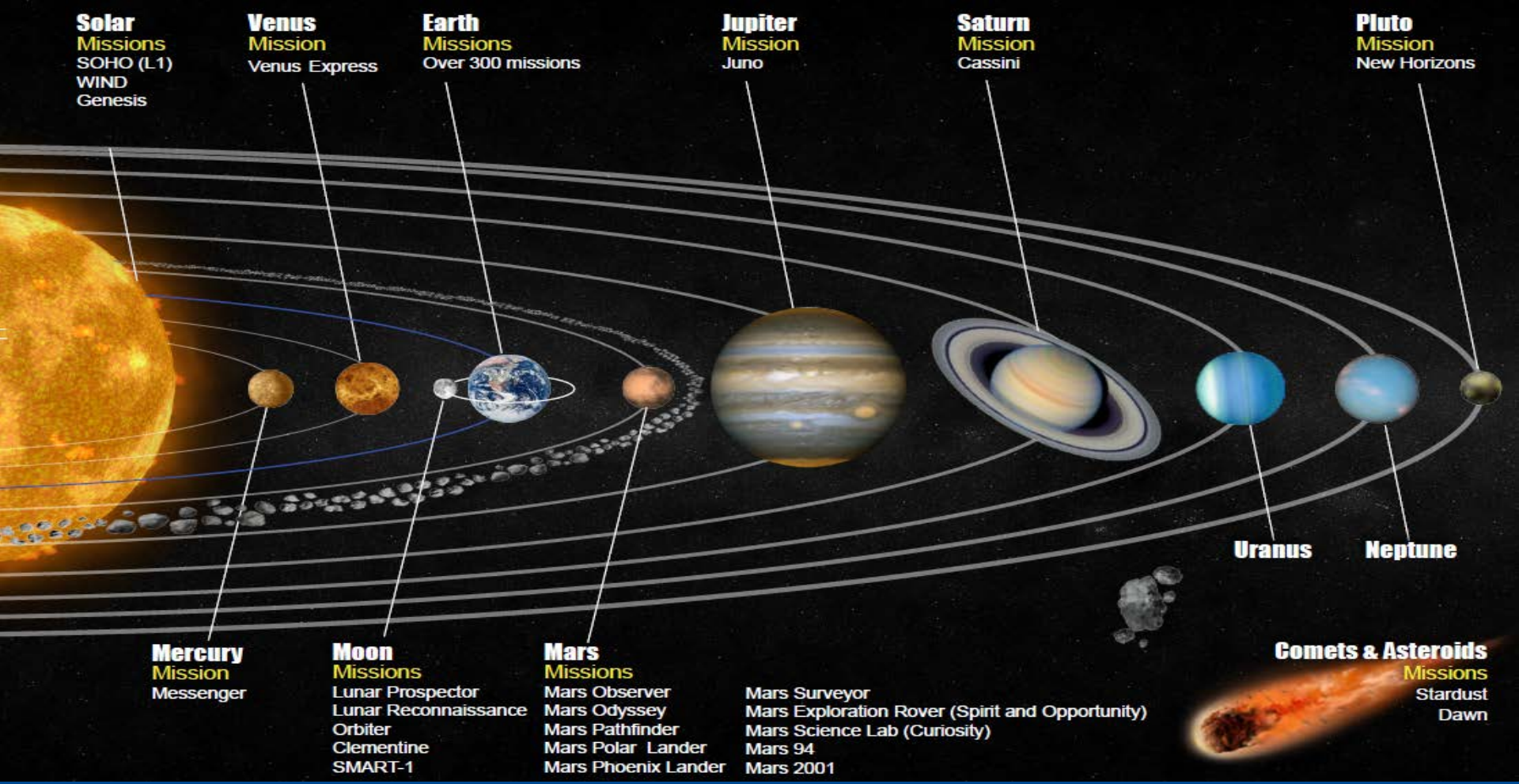
Propulsion and Environmental Systems




In-space Propulsion Systems


Advanced ECLSS Development


Bio Production Systems



Space Exploration Systems Products/Missions

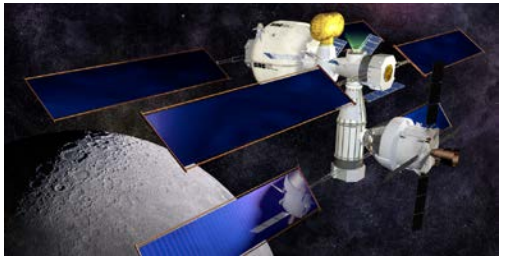
Free Flying, Science, Remote Sensing & Technology Test

On-Orbit Robotic Deployment, Servicing, Assembly & Repair

NASA Commercial Cargo Services

Crewed Missions

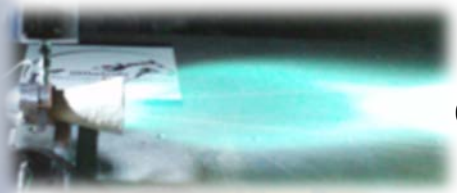
Exploration Support



Propulsion and Environmental Systems

- Aerospace development for 29yrs – propulsion, life support, Space Station systems.
- Unique, patented VORTEX engine demonstrated as rapidly scalable for multiple propellants
- Major enabler of commercial human space life support (Boeing, SNC, Bigelow, NASA)
- Demonstrated rapid, low-cost development, integration, and operation of complex space science systems
- Certified to ISO9001 and AS9100 (no major or minor findings in last 2 audits); Security clearance

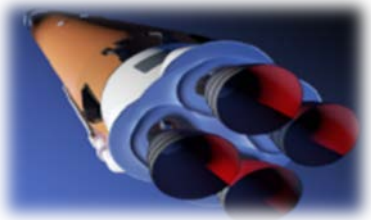
Propulsion Systems and Propellants

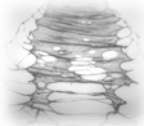


VORTEX
RCS Engines
0.1 lbf – 1,000 lbf

VORTEX
Upper Stage Engines
1,000 lbf – 100,000 lbf

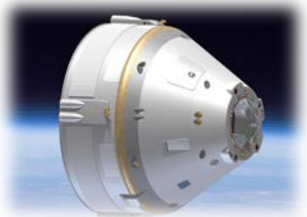
VORTEX Boost Stage Engines
100,000 lbf – 500,000 lbf

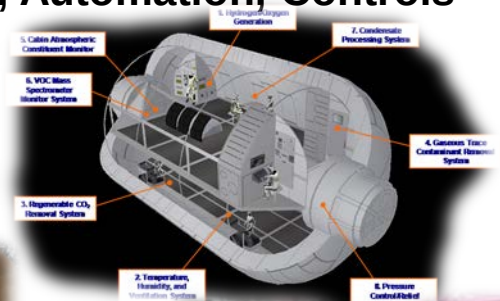




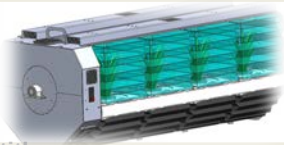
Advanced
Propellants
and Energetics

Human Support, Automation, Controls





BioProduction Systems

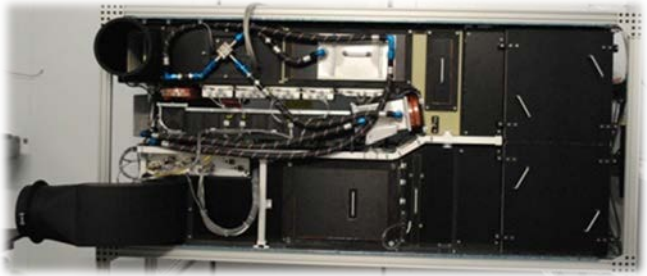
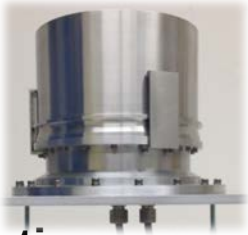


Environmental Control

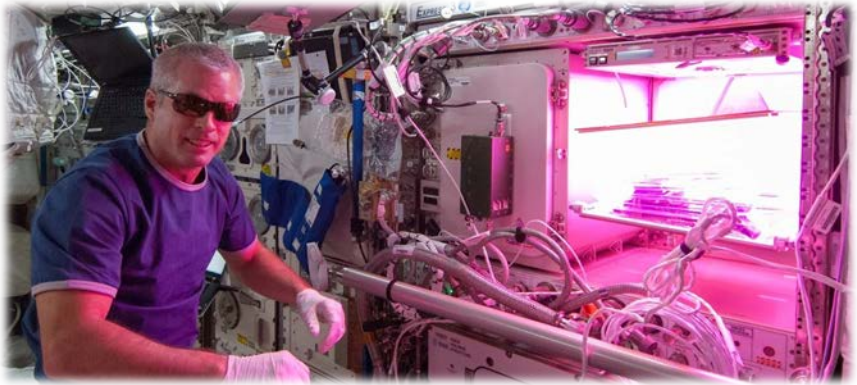
- **Pressure Control**
  - Valving/Regulators
- **Air Revitalization**
  - Oxygen production
  - CO2 Scrubbing (removal)
  - Gas Trace Contaminant Removal
  - Ventilation
  - Humidity Control
- **Water Processing**
- **Thermal Control**
  - Temperature Control
  - Thermal Transport
- **Trash Compaction/Stabilization**

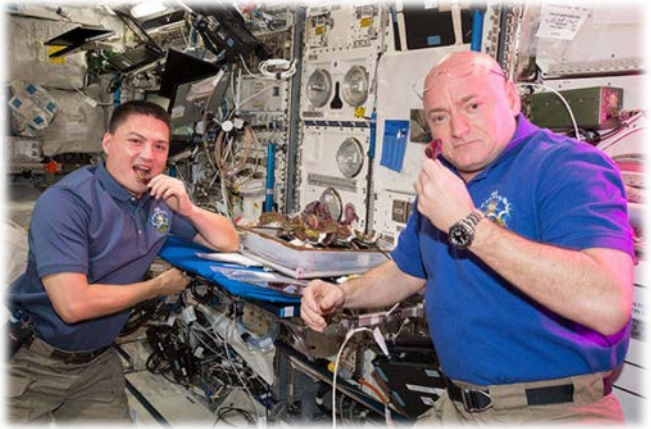





VEGGIE – Plant Growth System





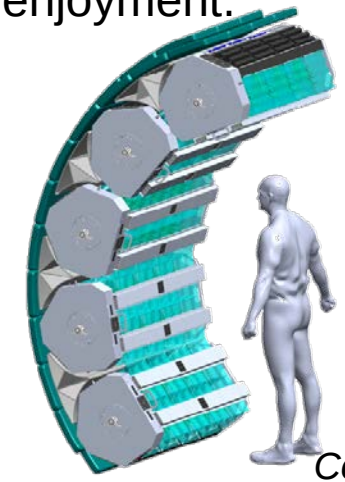
First time plants were grown for crew consumption

VEGGIE has been Growing Plants in Space for over 3 years!
A second VEGGIE is currently being installed due to its high utilization

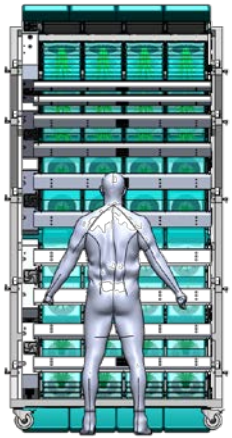
GreenWall – Extended Duration Applications

The GreenWall provides a significant increase in plant growing area, while minimizing the Equivalent System Mass (ESM), making plant growth during an extended duration mission a reality.

Benefits include fresh food, delivery of micronutrients to crew, augmented life support functions, and crew enjoyment.



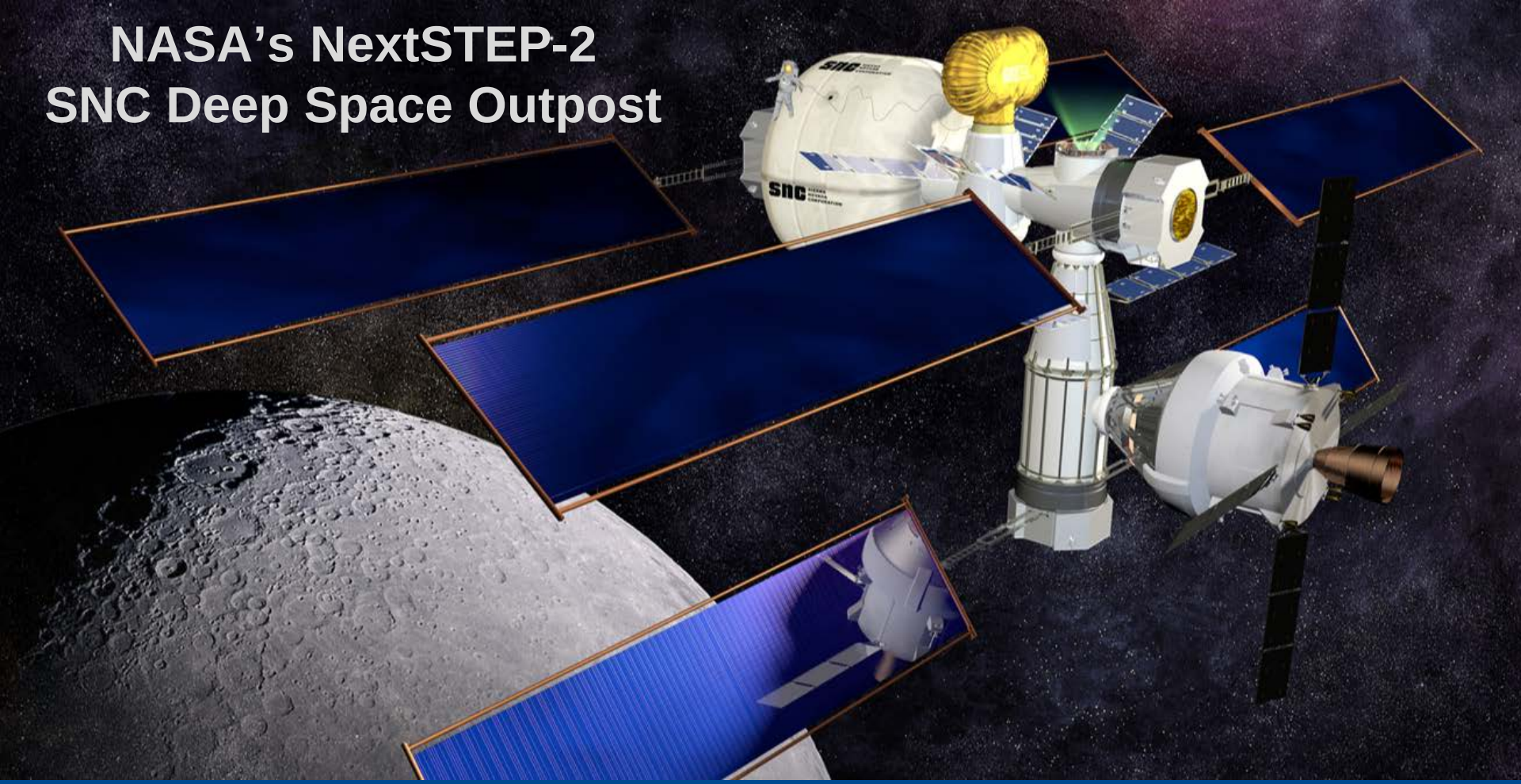
Concept



Prototype

Testbed for future developments

NASA's NextSTEP-2
SNC Deep Space Outpost



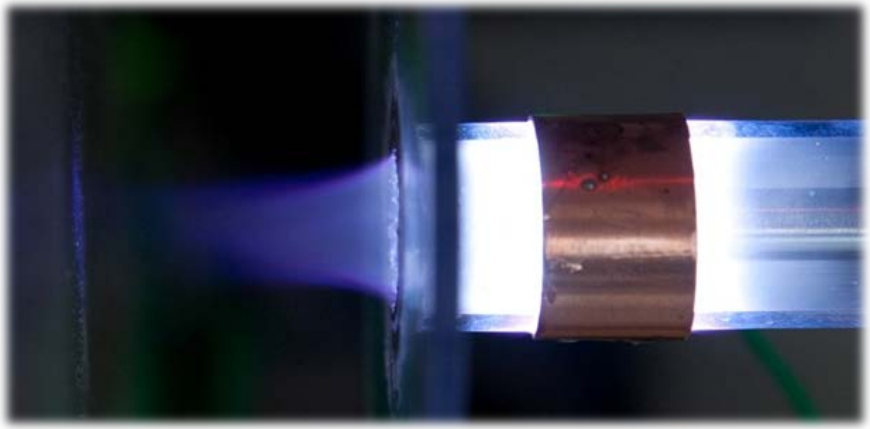
Heat Melt Compactor - Radiation Protection

- Logistical waste management system designed to process select dry and wet waste resulting from human life in space
- Trash dewatering and volume reduction using heat melt compaction to remove nearly 100% of water from trash while significantly reducing the volume of the trash
- Viable technology demonstrated for producing up to 16” square tiles, with potential use for radiation protection
- Plans have been developed to increase this technology through an ISS technology demonstration
- Alternative science proposed to study radiation remediation capabilities

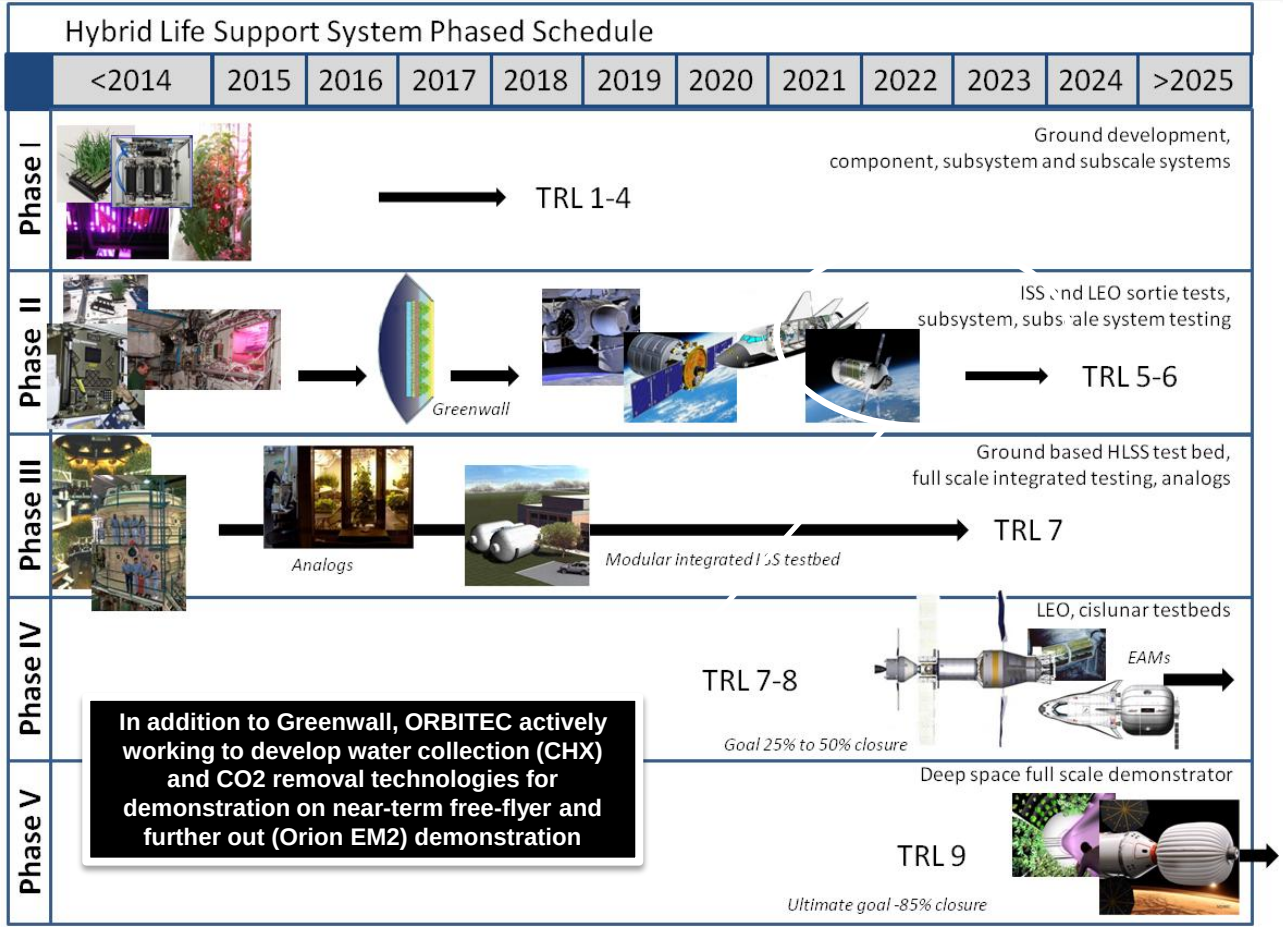
Trash Loaded, compacted, water reclaimed, trash stabilized

Food – Utensil - Laundry Sanitization

- **Utilizes a cold plasma technology to achieve an effective decontamination of food and utensils/laundry**
- **Demonstrated results showing effectiveness in sanitization**
- **Tested on food, such as fruits/vegetables, without discernable change in texture**



NextStep Roadmap



Dream Chaser Cargo System

Launch System

Cargo Module

Uncrewed
Dream Chaser Vehicle

The Best Payload Services Solution in the World

Capable: Highest cargo capacity, Can Dock or Berth

Safe: Gentle 1.5g reentry, runway landing, all non-toxic propulsion

Responsive: Immediate post-land access to full payload

Affordable: Highly reusable (15x), broad commercial services

Flexible: Cargo Disposal + return, stows in 5m launch fairings

Mature: Leverages 40+ years of Shuttle/X-plane experience

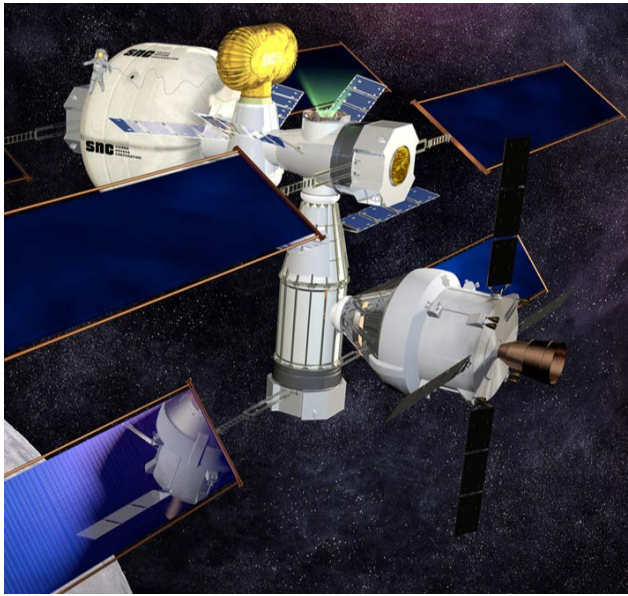
Committee on Biological and Physical Sciences in Space (CBPSS)

Given your organization's planned or potential future roles in developing transit or orbital vehicles and infrastructure in the next few decades, what thoughts do you have for the committee on any of the following:

1. What are the science issues or questions in space biology or physical sciences that may be important in advancing the development of planned or envisioned space technologies and systems?
2. Are there physical processes (such as fluids, combustion, or materials behavior in space) that have been identified as potentially requiring additional understanding to support future development?
3. Can you give us a picture of the demand that you see in your organization or in the larger aerospace community for knowledge about biological and physical behaviors in space over the next 10 years?
4. Where does your organization typically turn now for information on how biological and physical systems behave in space? For example, do you utilize published studies or on-line databases, rely on in-house expertise, conduct research, etc.?
5. When looking at future questions on how physical behaviors in low gravity might affect technology development or systems performance in space, do you think your organization would be likely to pursue these through in-house research, contract out investigations to smaller technology companies, or use some other approach?
6. Do you currently utilize NASA data and studies on how low gravity alters physical (and biological) processes? Would you anticipate using such data in the future? To what extent?
7. Can you talk about how you have, or would expect to, partner with NASA on answering questions about how physical (and biological) processes affect space technologies and systems?
8. Multiphase flows in life support systems are one example of how reduced gravity can alter a physical behavior in way that is highly detrimental to space technology performance. What kinds of similar issues do you see as being most important in the development of future space systems?

1. What are the science issues or questions in space biology or physical sciences that may be important in advancing the development of planned or envisioned space technologies and systems?

- How will we protect humans from the extreme radiation environments for multi-year transits?
  - Nominal, but high loads of radiation
  - Off-nominal radiation storms
- How can validate the minimal threshold of gravity that prevent a majority of bone loss and other physiological degredation?
  - We would like to consider the value and cost trade of Zero-g vs low-g environments
  - Low-g environments are typically more costly
  - May make fluid systems behave more naturally
  - At what point to begin to benefit the human in the system
  - Are Phobos/Deimos/Moon effective gravity for long duration
- What is best research to validate impacts of specific solutions on human performance; e.g., introduction of plant and food growth systems into ECLS
  - Needed to trade cost and effectiveness of operations in space
  - How can we quantify with accuracy?
  - How can this evaluation be rapidly?
- How can we distinctly learn long term affects of lower pressure habitats on the human system?



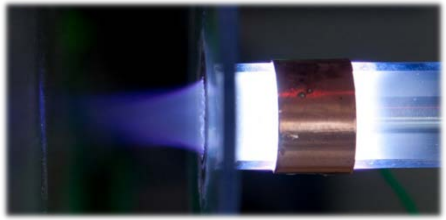
2. Are there physical processes (such as fluids, combustion, or materials behavior in space) that have been identified as potentially requiring additional understanding to support future development?

- Fluid and liquid collection
- Sustenance of proper consistency of two phase “solution”
  - Root modules
  - Particulate suspension in liquid / water
- Human performance benefits of using plants and food-growth techniques in life support
- Passive heat collection and transfer with fluids

VEGGIE Food Production & Science in Zero-g

Water-reduced waste configured in plastic wafer

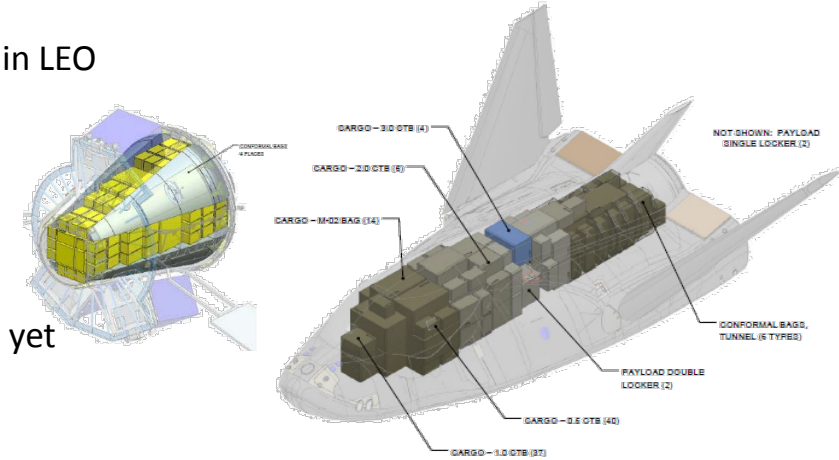
Low Temperature Plasmas for Sanitation




Next-Gen, Bio-integrated ECLSS

3. Can you give us a picture of the demand that you see in your organization or in the larger aerospace community for knowledge about biological and physical behaviors in space over the next 10 years?

- Flight of Dream Chaser could augment science flight capabilities in LEO
  - To, from, and with ISS
  - Away from ISS
  - Dedicated science modules
  - Soft return with near-immediate access
- Next 4 years will define basic long duration habitats
- Opportunities that could drive revolutionary approaches are not yet quantified from a science or human benefit.
  - Radiation impacts
  - Low pressure impacts
  - Impacts of partial gravity
- Dream Chaser platforms, modules, and flight vehicles could sponsor and facilitate much more rapid research
- How can we keep long-term science prioritized to human safety and performance that will enable revolutionary human space travel solutions?
  - Basic Research to find what we do not know
  - Applied Research to understand and quantify benefits, disadvantages, and value

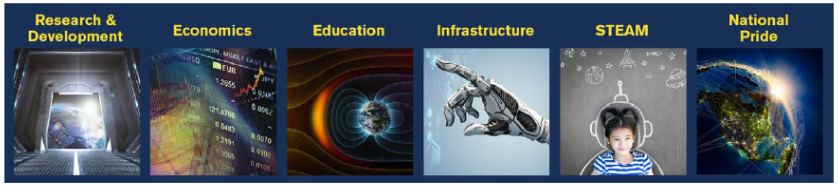


4. Where does your organization typically turn now for information on how biological and physical systems behave in space? For example, do you utilize published studies or on-line databases, rely on in-house expertise, conduct research, etc.?

- NASA and University research studies
- Internal work
- Teamed with experts (especially when involving human subjects)
- Heavy reliance on past science work; funding is more difficult when tied to schedule-driven developments
- SNC has an executed agreement for UN Mission
  - Significant opportunity for joint science
  - UN Nations need support and sponsorship in such research

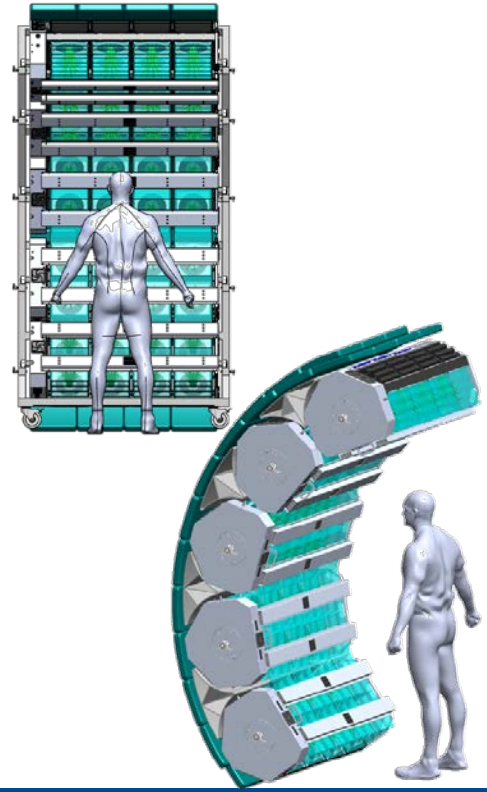
Benefits for Participating Countries

- **Research & Development:** of new space-related knowledge-based industries to support space science understanding and development of experiments in diverse economic sectors.
- **Economic:** growth in high technology fields.
- **Education:** formation of academic centers of excellence to study various aspects of space: space sciences, environmental sciences, atmospheric physics, etc.
- **Infrastructure:** creation of the supporting infrastructure for development of experiments, robotics for manipulating experiments and providing ground operations for (their) space missions.
- **STEAM:** inspire participation in the space program, encouraging education and work in science, technology, engineering, arts and mathematics (STEAM).
- **Pride:** of supporting international cooperation and global promotion of peaceful uses of outer space.



5. When looking at future questions on how physical behaviors in low gravity might affect technology development or systems performance in space, do you think your organization would be likely to pursue these through in-house research, contract out investigations to smaller technology companies, or use some other approach?

- Conduct the research in-house if possible
- Teaming is best approach, where research and results can be directly assessed by developments.
  - Supporting SNC developments in parallel with generally applied research
  - Jointly sponsored with NASA or other funding agency; potentially under SAA or PPP
- Dream Chaser (short or long duration) research and science is encouraged
- Small Business teaming is used; we are on several support / commercialization programs
- Sensitive issues that constrain external research support (not new)
  - ITAR
  - Control of IP and Competition sensitive material
  - New IP sharing
- Opportunities (significant desire to on-board talent that understands and can contribute)
  - Transition of grad and undergrad students into jobs
  - Direct application of research results

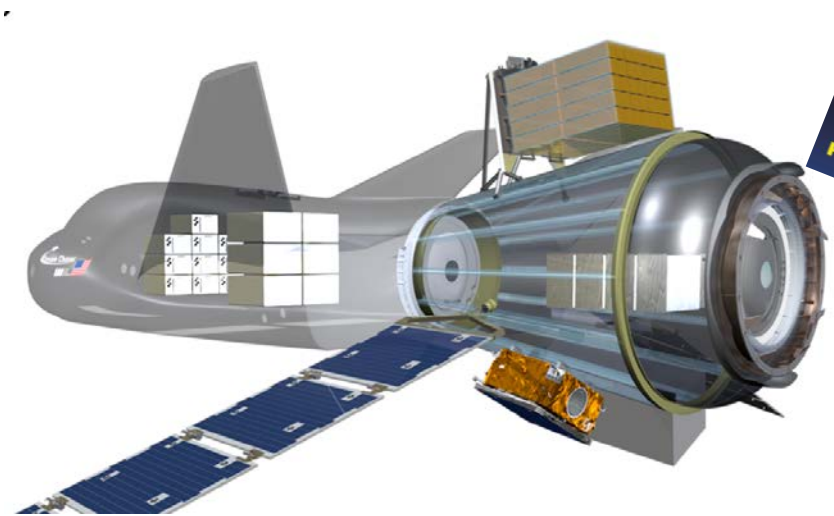


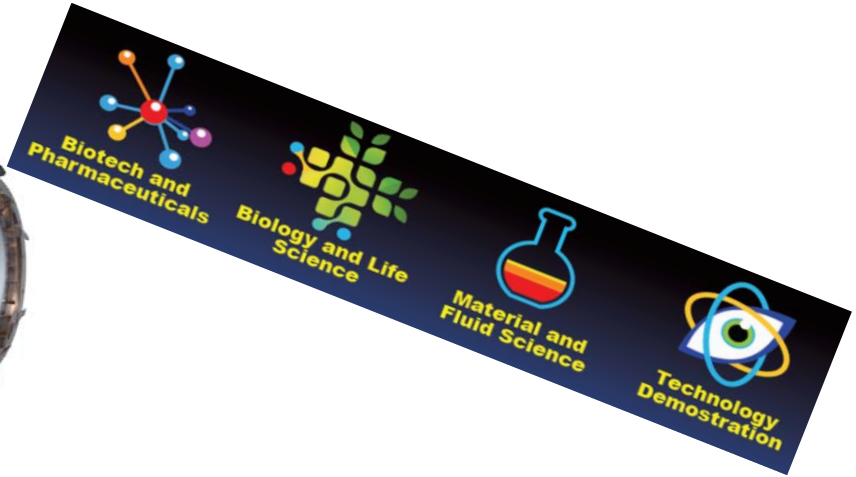
6. Do you currently utilize NASA data and studies on how low gravity alters physical (and biological) processes? Would you anticipate using such data in the future? To what extent?

- SNC relies strongly on NASA research and extends applied research from the more general results.
- Much of the data is anecdotal and requires more refined research and assessments to make applicable. We appreciate the broad data but then need to investigate the impacts of specific potential solutions.
  - We use the basic research to understand the overall benefits and risks of certain solutions; if an area is unknown or not well researched, we will likely avoid the area to avoid safety and other unknown problems. In many cases we understand a benefit of a particular solution but cannot quantify, so the solution has less value because on un-validated value.
  - We need to find ways to drill down into additional details after initial results ➔agile redirection of research is helpful.
- Detailed studies in the future of how to contain, control, manage microbial growth will continue to be important.
- We anticipate being able to facilitate and sponsor more science and research for our own needs and the needs of others

7. Can you talk about how you have, or would expect to, partner with NASA on answering questions about how physical (and biological) processes affect space technologies and systems?

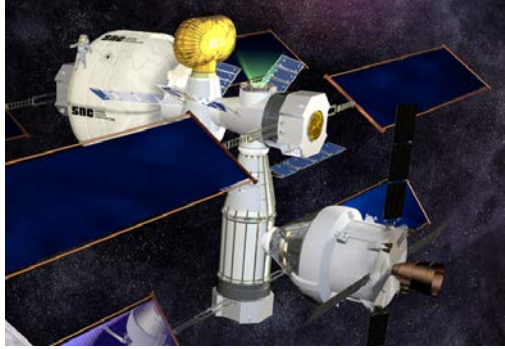
- Largely through a NASA center in an effort as a team member
- SAA and PPP efforts
- Proposing solutions with research adjacent to developments
- Facilitating and supporting science on the Dream Chaser platforms





8. Multiphase flows in life support systems are one example of how reduced gravity can alter a physical behavior in way that is highly detrimental to space technology performance. What kinds of similar issues do you see as being most important in the development of future space systems?

- Long term collection and management of contaminants that are not easily cleaned or flushed
  - Microbial
  - Chemical build-ups
  - Filters and other manageable contaminant collectors
  - Means of constant sanitation (e.g., low temp plasma for food, towels, clothes, instruments, sensitive surfaces/equipment)
- Human performance in long duration habitats
- Radiation impacts on humans
- Long duration effects of low pressure environments
- Combined effects of zero g, space radiation, low pressure
- Integration of resources from planetary surfaces (we have generated water with lunar simulant in NASA analog testing environments)



SNC is uniquely positioned and ready to utilize and aid Science in Space

- Adopt research results into innovative solutions
- Facilitate and Sponsor new research on the Dream Chaser platforms
- Team with experts to guide solutions for long duration space