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PERSPECTIVES ON LOW EARTH ORBIT ECOSYSTEMS
CASIS BRIEFING TO THE CBPSS

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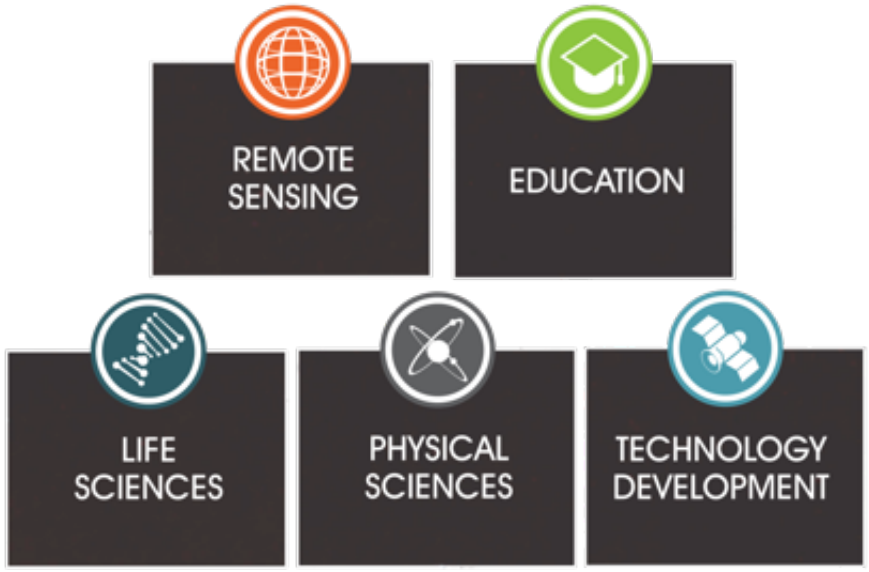
THE ISS U.S. NATIONAL LAB

The ISS U.S. National Lab provides opportunity for research and discovery targeted to definitive impacts on Earth.

The opportunities on the ISSNL are wide-ranging:



ISS U.S. NATIONAL LABORATORY

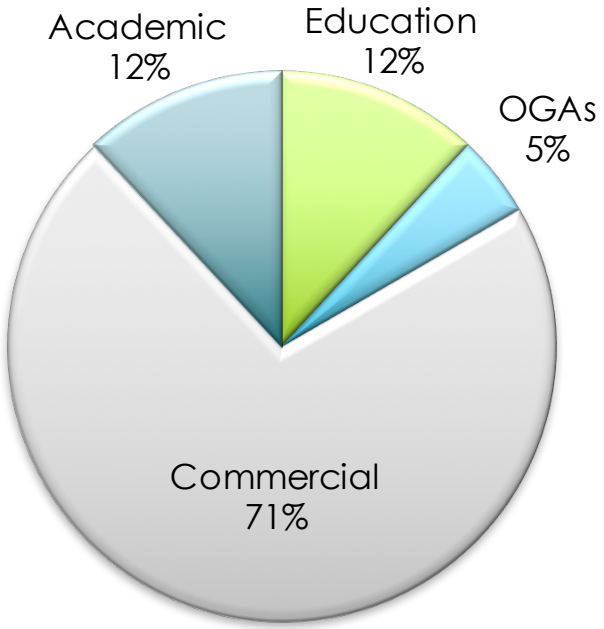
NASA CASIS

POWERED THROUGH PARTNERSHIP

IMPROVE LIFE ON

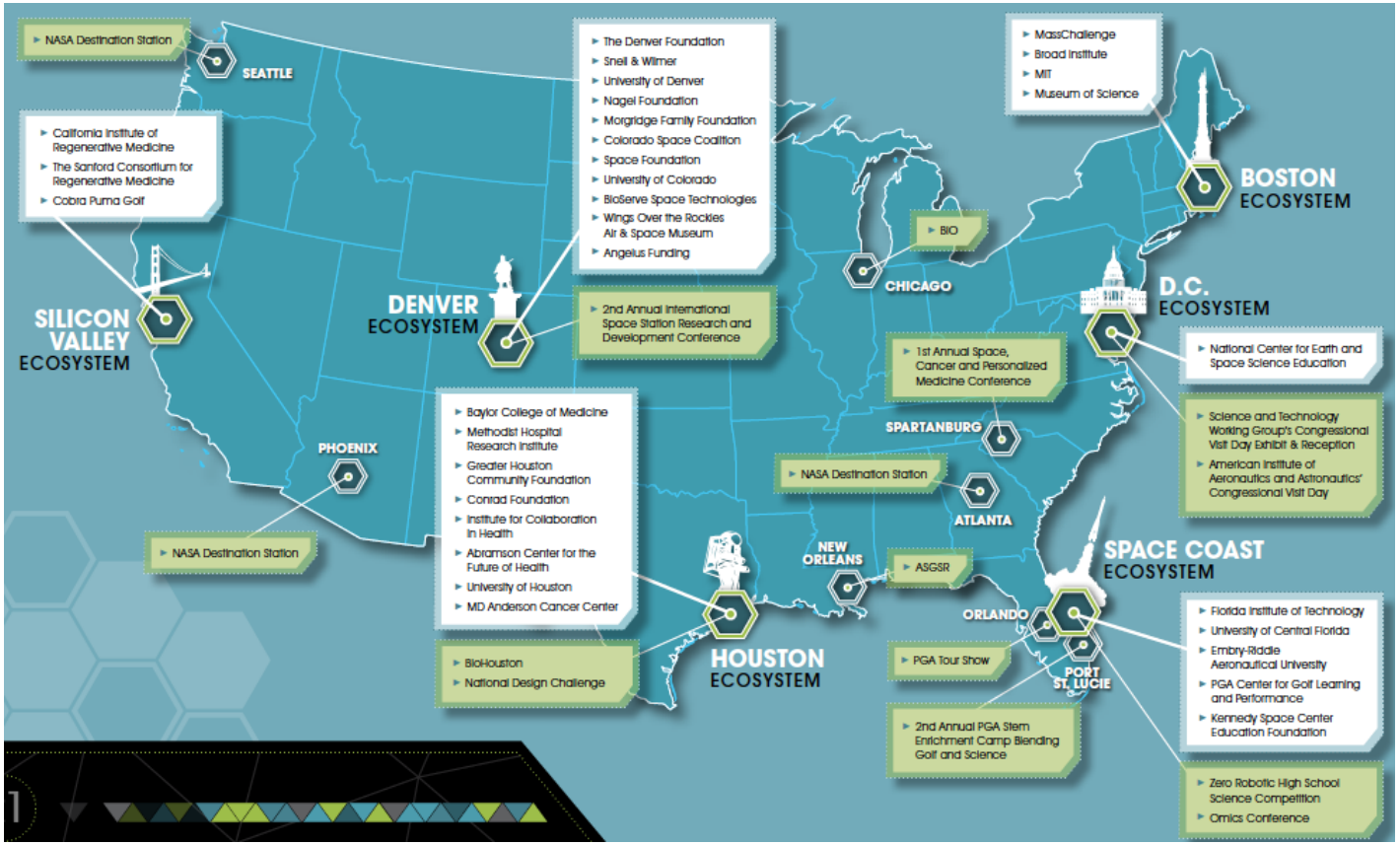
EVOLVING ISS NATIONAL LAB – BIG PICTURE

- **Commercial engagement** – 71% of FY15 CASIS-sponsored research projects represent commercial companies
- **Robust portfolio** – CASIS has evaluated more than 200 proposals since inception
  - Awarded more than $20M in seed money to ~100 projects
- **Sponsored program model** – Leveraged the financial resources of other outlets with our ability to manifest ISS National Lab flight opportunities
  - NSF – $1.8 million investment a significant step to larger scale funding partnerships
  - NIH – In discussions with the National Center for Advancing Translational Sciences (NCATS)
- **Network building** – Developing/managing partnerships across targeted geographic ecosystems
  - e.g., MassChallenge in Boston, Houston Angel Network in Houston, Space Angels Network in SoCal, Lux Capital in CA

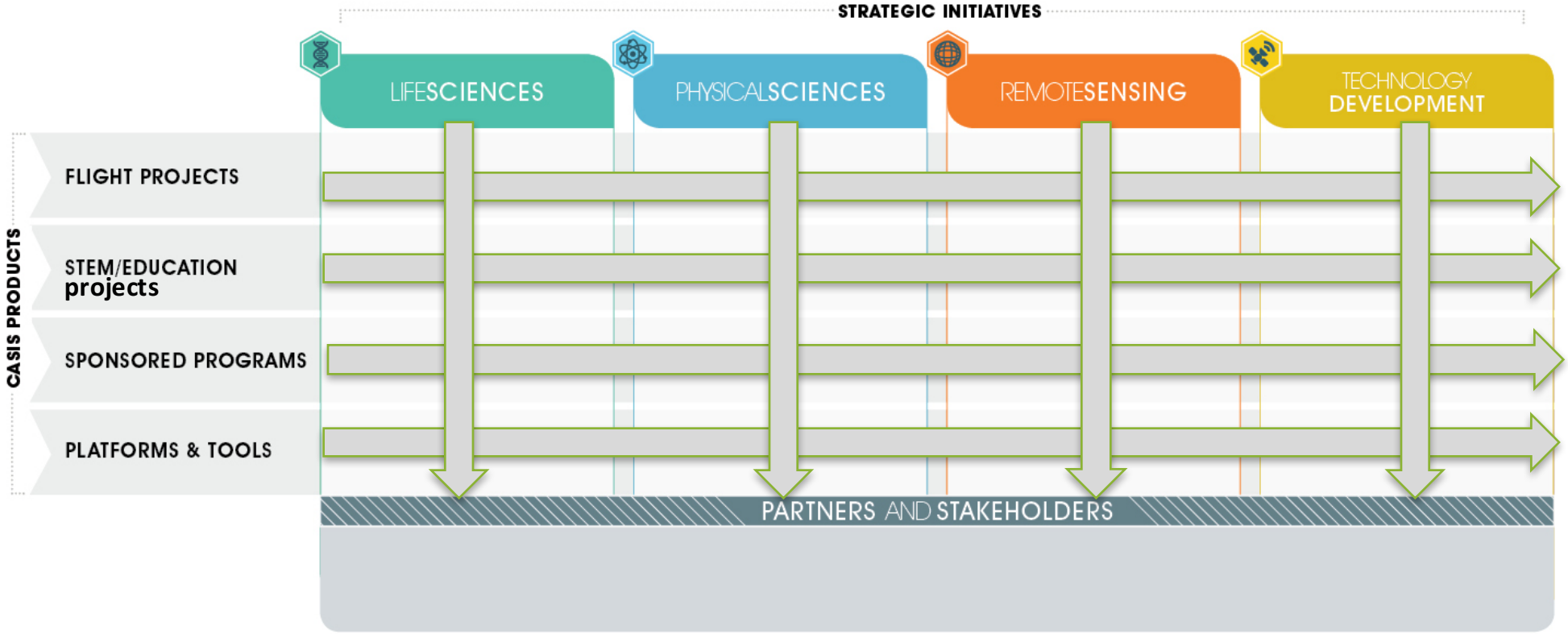


*OGAs – other government agencies

WE BEGAN BY DEVELOPING GEOGRAPHIC ECOSYSTEMS



AND THEN WE DEVELOPED PRODUCTS AND STRATEGIC VERTICALS



CASIS COMMERCIAL SUCCESS ACROSS OUR VERTICALS

Life Sciences

ACCELERATED DISEASE MODELS: MUSCLE / BONE / WOUND HEALING

Lilly
NOVARTIS
ONCOLINX

DRUG DELIVERY SYSTEMS

Lilly
HOUSTON Methodist LEADING MEDICINE

POINT OF CARE DIAGNOSTICS & ON CHIP TECHNOLOGIES

NANOBIOSYM
SQZBIOTECH
CAMMED
Zaiput Flow Technologies
NOVOPYXIS
1Drop Diagnostics

DRUG DISCOVERY & DEVELOPMENT (PROTEIN CRYSTALLIZATION)

Lilly
MERCK Be well
iXpressGenes
TATE & LYLE

MICROGRAVITY ENABLED NOVEL MATERIALS

Astrileux
A2M

Physical Sciences

INDUSTRIAL MATERIALS / CONSUMER PRODUCTS

nemak
COBRA PUMA GOLF
Ras Labs
Milliken
P&G

ADDITIVE MANUFACTURING

DSI
MADE IN SPACE

Remote Sensing

EARTH OBSERVATION

VISIDYNE
gumstix dream, design, deliver
Honeywell

Technology Development

Space Tango
ASTRIUM
NovaWurks
intuitive MACHINES

AND ON THE HORIZON…

Life Sciences

Physical Sciences

Remote Sensing

Technology Development

SPONSORED PROGRAMS: FLIGHT AND STEM

- Tailored program aimed at solving a customer's challenge and/or driving new innovation by finding and flying cutting edge research
- Linking ISS as innovative platform and relevant researchers with customer challenge.
- Stimulates and promotes collaborative research, innovation and new startups through academic, commercial and government partnerships

USING COMPETITIONS AS PART OF SPONSORED PROGRAMS

Galactic Grant Competition

CASIS

MASSACHUSETTS LIFE SCIENCES CENTER
Investing in the State of Innovation

THE MASSACHUSETTS LIFE SCIENCE CENTER AND CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE GALACTIC GRANT COMPETITION SOLICITATION

Program Overview:

The Center for the Advancement of Science in Space and the Massachusetts Life Sciences Center invite you apply to the "Galactic Grant Competition", which has been established to enable Massachusetts=based life sciences companies to access the International Space Station National Lab to conduct research and/or technology development in a truly one of a kind environment, featuring:

Award:

Up to $500,000 is available for costs associated with developing and flying the project (the cost of the project is jointly developed between CASIS and the company through the proposal development process.) Money is dispersed according to a mutually agreed timeline tied to milestones.

PR Newswire

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Governor Patrick, Massachusetts Life Sciences Center, and CASIS Announce Grant Competition to Support Research on the International Space Station U.S. National Laboratory

"Galactic Grant Competition" will fund innovative industry research; grant will also fund STEM initiatives for Massachusetts schools

BOSTON, Nov. 13, 2014 /PRNewswire-USNewswire/ -- Governor Deval Patrick, the Massachusetts Life Sciences Center (MLSC), and the Center for the Advancement of Science in Space (CASIS) today announced the "Galactic Grant Competition," a new collaboration that will provide Massachusetts-based companies a unique opportunity to access the International Space Station (ISS) to conduct life sciences research. The grant competition, funded by MLSC, will be open for applications from December 1, 2014 through April 3, 2015 and will encourage companies to take advantage of the distinct attributes of the ISS research platform for life sciences initiatives. The microgravity environment on the ISS has profound and unique effects on biological phenomena and can enable discoveries with terrestrial applications, including drug discovery, development, delivery, and diagnostics.

BUSINESS ACCELERATOR RESEARCH COMPETITIONS

MassChallenge Awards

- **Neural Analytics** – Non-invasive measurement of intracranial pressure
- **Quad Technologies** – Stem cell separation technology
- **Benevolent Technologies for Health** – Low-cost reconfigurable material designed for prosthetic sockets
- **Ras Labs** – Synthetic muscle and nanomaterials
- **Vecoy Nanomedicines** – Nanomedicines for the treatment of HIV/AIDS, Hepatitis-C and other viral infections
- **Silverside** – Radiation detection technology
- **Cam Med** – Electrolysis generates bubbles in order to improve the methods of dosage control in a device that can deliver multiple medication through the skin
- **Novopyxis** – Seeking to improve a drug delivery device by studying how the drugs penetrate and spread once they've entered a substance mimicking human skin
- **SQZ Biotech** – Novel method for delivering large molecules into cells by using a microfluidic chip to physically squeeze cells
- **LaunchPad** - Commercialize a synthetic bone adhesive that can adhere to both bone and metal within minutes to provide immediate load-bearing strength.
- **Biorasis** - monitor the role of diffusion in glucose transport and potentially improve the accuracy of the their sensor, providing a more reliable product for the diabetic community.

Rice Business Plan Award

- **A-76 Technologies** – Thin film protective coatings
- **DexMat** – Carbon nanotube cables

OUR MESSAGE: IT'S FIRST AND FOREMOST ABOUT THE OPPORTUNITIES FOR CUTTING EDGE SCIENCE

Microgravity

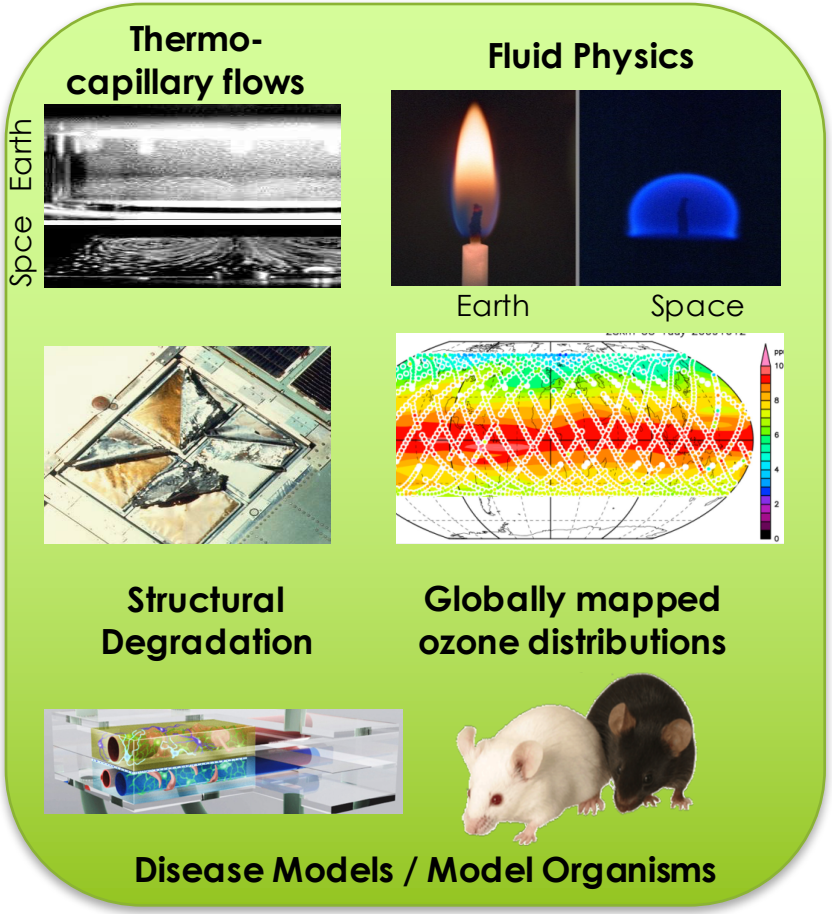
Alters many observable phenomena

Extreme Conditions of Space

Extreme heat and cold cycling
Ultra-vacuum
Atomic oxygen
High energy radiation
Debris impact

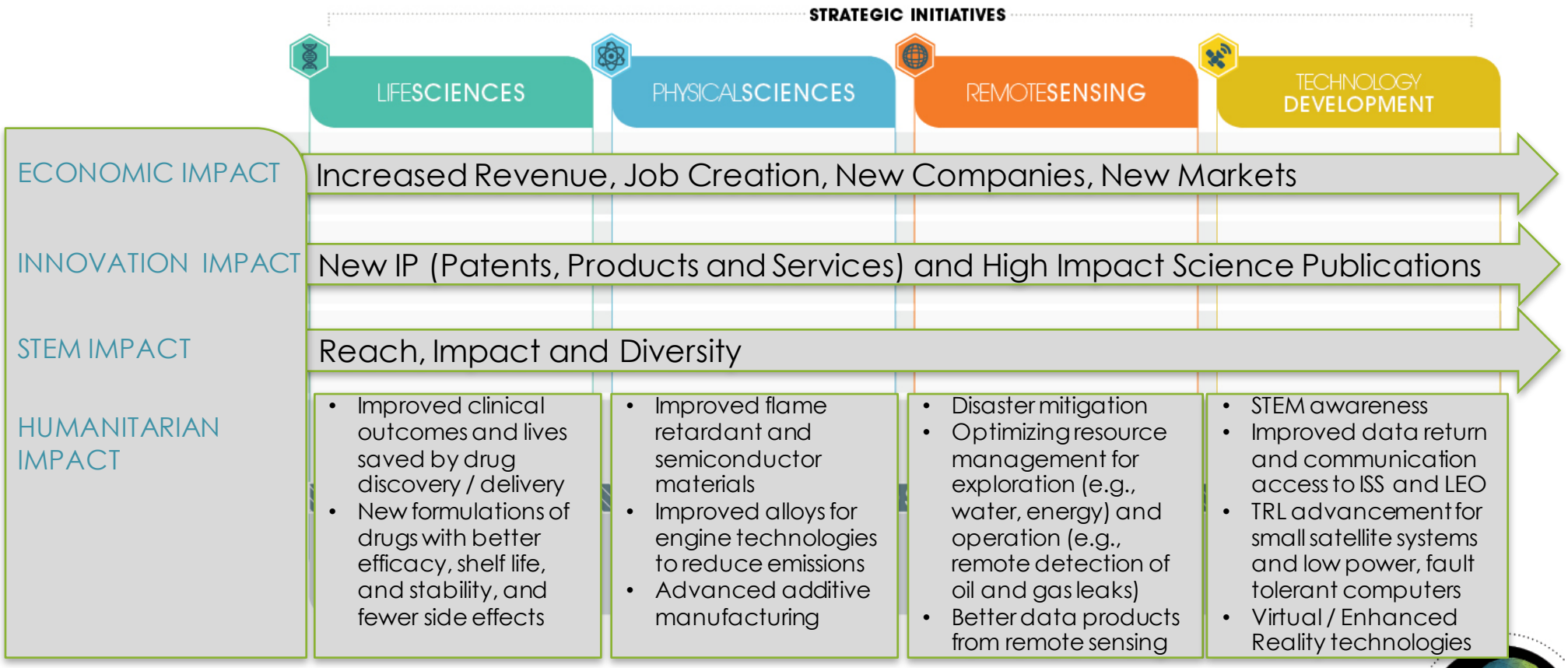
Vantage Point/Earth Observation

Orbital path over 90% of Earth's population
Altitude ~240 mi (400 km)
Improved spatial resolution
Variable lighting conditions



All images courtesy of NASA and the NIH.

MAPPING ISSNL INITIATIVES TO EARTH BENEFIT

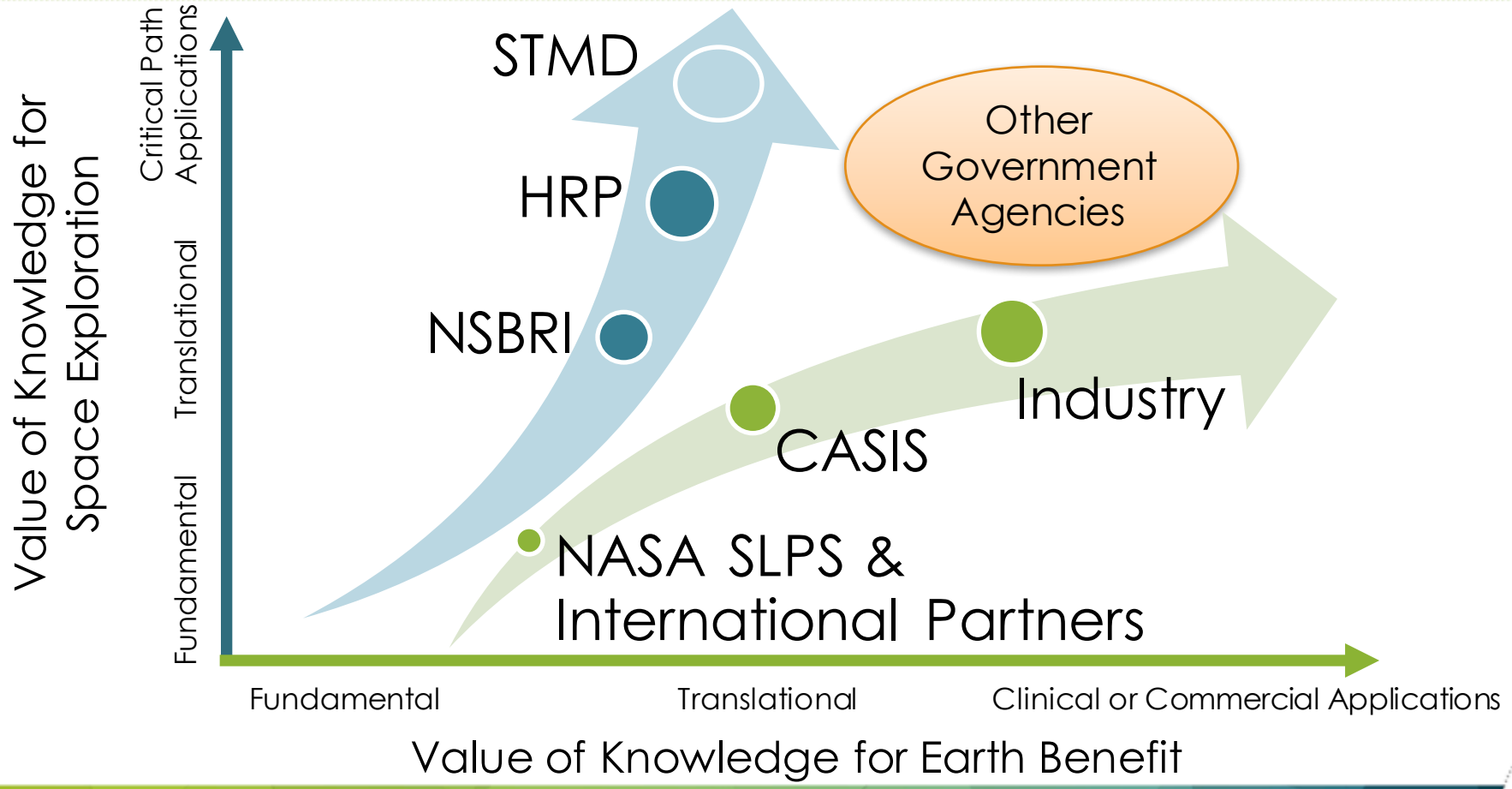


ISS NATIONAL LAB: CUSTOMER FEEDBACK

- **"The ISS National Lab provides a unique opportunity for innovative Earth observation missions, most notably serving as a robust, highly functional platform for remote sensing technology demonstration and data fusion"** (Dr. James Goodman, HySpeed Computing)
- **"Nano3D's technology is a good example of progress enabled by CASIS. If it weren't for CASIS Nano3D's technology would not have been adapted to be used as a general tool for biological experimentation on the ISS"** (Dr. Glauco Souza, Nano3D Biosciences, Inc.)
- **"Our accomplishments would not have been possible without the funding and support from CASIS to perform the extensive ground work, launch preparations, spaceflight management, and postflight analyses."** (Dr. Joseph Ng, iExpressGenes)
- **"Thanks to support from CASIS, we have established a Center for Space Nanomedicine at HMRI, which is fully dedicated to nanotechnologies developed in space for medical applications on Earth and involves multiple flight experiments over the next five years"** (Dr. Allessandro Grattoni, Houston Methodist Research Institute)
- **"CASIS has made extraordinary progress in a variety of experiments being conducted on the ISS National Lab that will benefit humanity….from fundamental scientific understanding to practical applications in extremely challenging environments."** (Dr. Lenore Rasmussen, Ras Labs)

LEO COMMERCIALIZATION

R&D OBJECTIVES OF ISS NATIONAL LAB STAKEHOLDERS



PROMOTING LEO ECOSYSTEM DEVELOPMENT

Enabling "demand side" interest alongside NASA, commercial service providers, and others

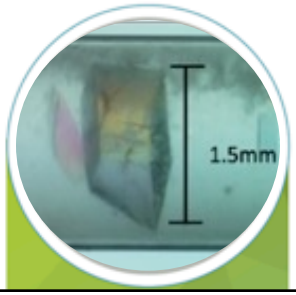
- The CASIS mission is to maximize the value of the ISS to the nation by developing and managing a diversified R&D portfolio based on U.S. national needs for basic and applied research.
  - *CASIS is thus in a position to stimulate demand that could attract business players to invest in building space-based platforms, privately invested infrastructure, and R&D.*
- CASIS is not in this alone, and looks to NASA, other government agencies, and businesses such as SpaceX, Orbital ATK, Bigelow Aerospace, Nanoracks to help create demand.
  - *Each plays a unique role in promoting LEO ecosystem development.*
  - *Businesses are especially anxious to create demand, to show their investments will create revenue.*

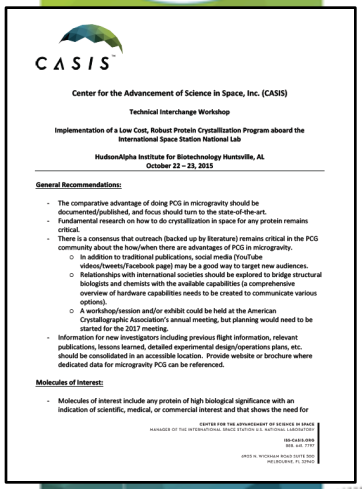
FOCUS AREA: PROTEIN CRYSTALLIZATION

- Why this area?
  - *Significant amount of prior research*
  - *Most traction with industry—already working with Merck and Eli Lilly*
  - *Farther along the "research pathway"*

- Demand will be stimulated by
  - *Offering multi-mission commitments to R&D community, including opportunities to partner with OGA's (e.g., DOE)*

Image courtesy of Dr. Joe Ng





CASIS

Center for the Advancement of Science in Space, Inc. (CASIS)

Technical Interchange Workshop

Implementation of a Low Cost, Robust Protein Crystallization Program aboard the International Space Station National Lab

HudsonAlpha Institute for Biotechnology Huntsville, AL
October 22 – 23, 2015

General Recommendations:

- The comparative advantage of doing PCG in microgravity should be documented/published, and focus should turn to the state-of-the-art.
- Fundamental research on how to do crystallization in space for any protein remains critical.
- There is a consensus that outreach (backed up by literature) remains critical in the PCG community about the how/when there are advantages of PCG in microgravity.
  - In addition to traditional publications, social media (YouTube videos/tweets/Facebook page) may be a good way to target new audiences.
  - Relationships with international societies should be explored to bridge structural biologists and chemists with the available capabilities (a comprehensive overview of hardware capabilities needs to be created to communicate various options).
  - A workshop/session and/or exhibit could be held at the American Crystallographic Association's annual meeting, but planning would need to be started for the 2017 meeting.
- Information for new investigators including previous flight information, relevant publications, lessons learned, detailed experimental design/operations plans, etc. should be consolidated in an accessible location. Provide website or brochure where dedicated data for microgravity PCG can be referenced.

Molecules of Interest:

- Molecules of interest include any protein of high biological significance with an indication of scientific, medical, or commercial interest and that shows the need for

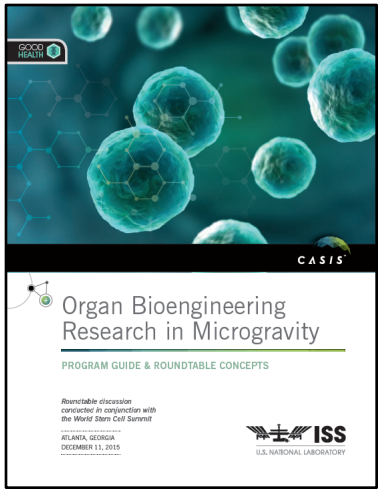
FOCUS AREA: ORGAN/TISSUE BIOENGINEERING

Why this area?

- *Value in LEO environment to stem cell research and the organization of cell/tissue structures.*
- *To date, the demand is mostly among smaller players, but has great potential for larger business.*

Demand will be stimulated by:

- *Leveraging ongoing parallel efforts toward the goal of organ bioengineering, including academia, industry, not-for-profit institutes, and OGAs including NIH, DoD, HHS, NIST, NSF, and OSTP.*
- *3D Microphysiological Systems for Organs-On-Chips Research Challenge, with $1M in CASIS funding*
- *Vascularization Challenge in collaboration with the Methuselah Foundation, with $500K+ in NASA STMD funding*



FOCUS AREA: ON-ORBIT PRODUCTION

- **Why this area?**
  - *Superior optical fibers produced in parabolic flights; potential value in manufacturing exotic fibers*
  - *Additive manufacturing in LEO has been demonstrated*
  - *Process to "heal" silicon carbide wafers in LEO*

- **Demand will be stimulated by:**
  - *Partnering with industry through business plan competitions and challenges*
    - *Competitions for the most relevant technologies to solve key industry problems*
  - *Incremental funding to help more proof-of-concept flights for companies that could then attract external capital investment*
  - *Development of new consortia or carve niche within existing collaborations*