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California Institute of Technology

NASA Innovative Advanced Concepts (NIAC)

at the Jet Propulsion Laboratory

Andrew A. Shapiro, Ph.D.
Jet Propulsion Laboratory, California Institute of Technology

AGENDA

- THE NIAC PROGRAM AT JPL

- FOUR EXAMPLES

  - **Automaton Rover for Extreme Environments,**
    PI: Jonathan Sauder

  - **Direct Probe of Dark Energy Interactions with a Solar System Laboratory**,
    PI: Nan Yu

  - **Direct Multipixel Imaging and Spectroscopy of an Exoplanet with a Mission to the Focus of the Solar Gravitational Lens,**
    PI: Slava Turyshev

  - **TransFormers: Building a Solar Power Infrastructure on the Moon**
    PI: Adrian Stoica

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NIAC AT JPL

- JPL has been enthusiastically involved with NIAC since its reincarnation in 2012
- JPL has submitted and won proposals each year since 2012
- The JPL engineers and scientists use NIAC as a forum to try out new – out-of-the-box ideas for potential future JPL/NASA missions
- This is what they do for fun!

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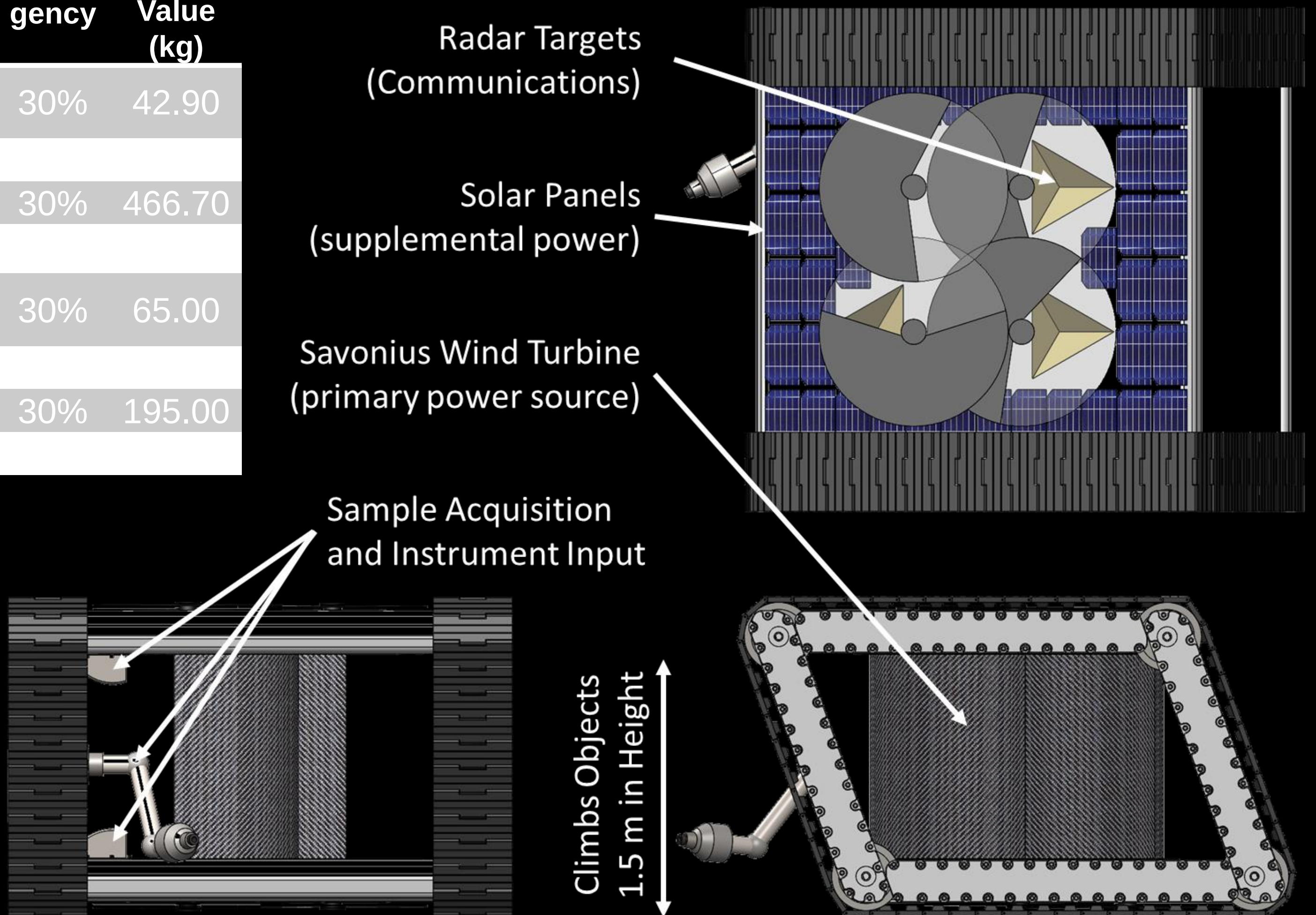
AUTOMATON ROVER FOR EXTREME ENVIRONMENTS

Phase II NIAC

Jonathan Sauder, Evan Hilgemann, Jessie Kawata, Katie Stack, Aaron Parness, Michael Johnson

THE AUTOMATON ROVER CONEPT

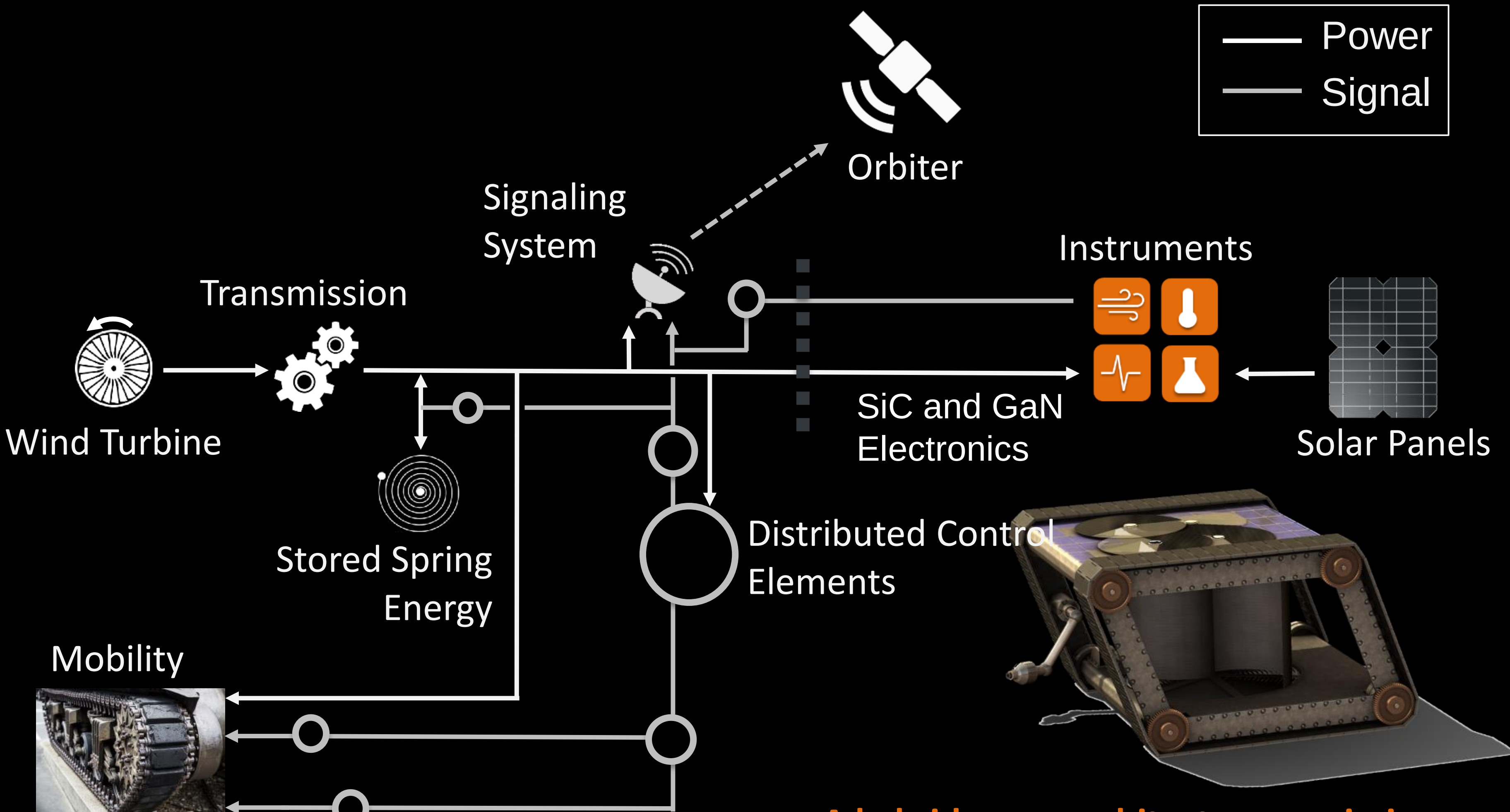
Item	Mass CBE (kg)	Contin-gency	Mass Estimate Value (kg)
Power Generation	30.03	30%	42.90
Power Storage			
Locomotion	326.69	30%	466.70
Communication			
Control/Sensing Mechanisms	45.50	30%	65.00
Structure			
Science Payload	150.00	30%	195.00
Total Mass			



2018 IEEE Aerospace

DEVELOPED CONCEPT

Mobile Platform for High Temperature Instruments



A hybrid rover architecture maximizes performance.

2018 IEEE Aerospace

DIRECT PROBE OF DARK ENERGY INTERACTIONS WITH A SOLAR SYSTEM LABORATORY

PI: Nan Yu

Study Team:,

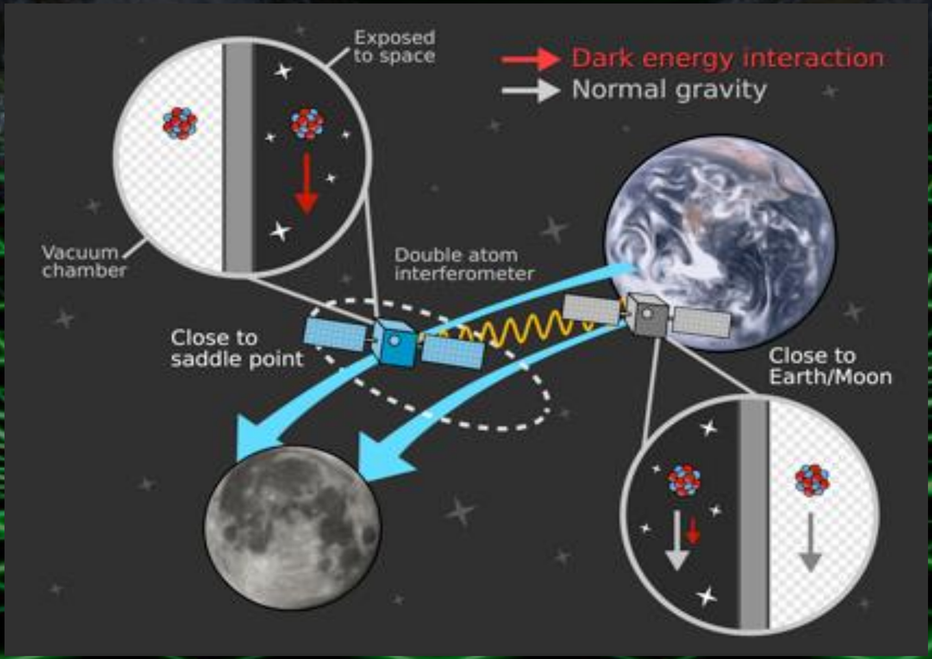
Jérôme Gleyzes, Jefferey Jewell, Sheng-wey Chiow, Olivier Doré, Jason Rhodes, and Eric Huff

Jet Propulsion Laboratory, California Institute of Technology

Phil Bull and Holger Müller

University of California, Berkeley

- Astrophysics observations confirmed the existence of dark energy for the accelerated expansion of the universe.
- If a dark energy scalar field exists, we expect it interacts with normal matter, with strength comparable with the gravitational force - extra force.
- The scalar field interaction with normal matters is environment-dependent and is screened (suppressed) in the solar system.
- The objective of the NIAC study is to look for special environments and regions in the solar system for less suppressed signals and use exquisite quantum atomic sensors for the extra weak force detection.
- Experiments of direct detection of dark energy scalar fields elucidate the nature of dark energy, complemental to observational dark energy missions.



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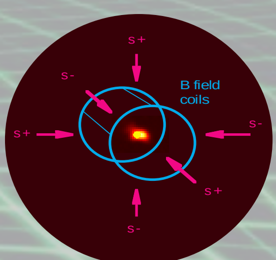
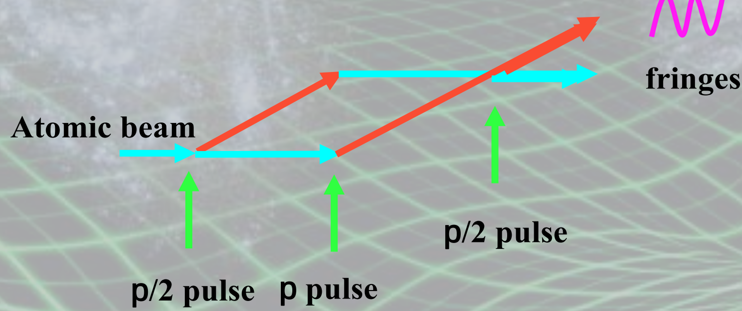
Technology: Quantum atomic weak force sensors with atom interferometry

- Totally free-fall atomic particles as ideal proof masses
- Quantum matter-wave interference for displacement measurements
- Intrinsic high stability of atomic system
- Measurements in diverse environments from very close a high mass density to totally in open space far away from local masses

Freefall atomic test mass + ***Quantum atom-wave interference for displacement measurement*** + ***Atomic system stability***

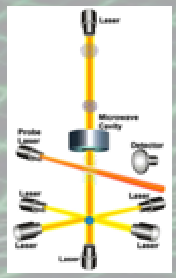


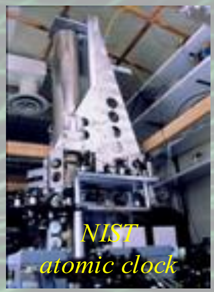
Laser-cooled atoms at μK and below



Atom interferometer (AI)

(laser-based atom optics)





Atomic systems are extremely stable as used in atomic clocks

DIRECT MULTIPIXEL IMAGING AND SPECTROSCOPY OF AN EXOPLANET WITH A MISSION TO THE FOCUS OF THE SOLAR GRAVITATIONAL LENS

Slava G. Turyshev[1], Michael Shao[1], Nathan Strange[1], Mark R. Swain[1], Leon Alkalai[1], Hanying Zhou[1], Janice Chen[1], Stacy Weinstein-Weiss[1], Nitin Aurora[1], Dmitri Mawet[1], Viktor Toth[2], James DeLuca[3], and Jared R. Males[4]

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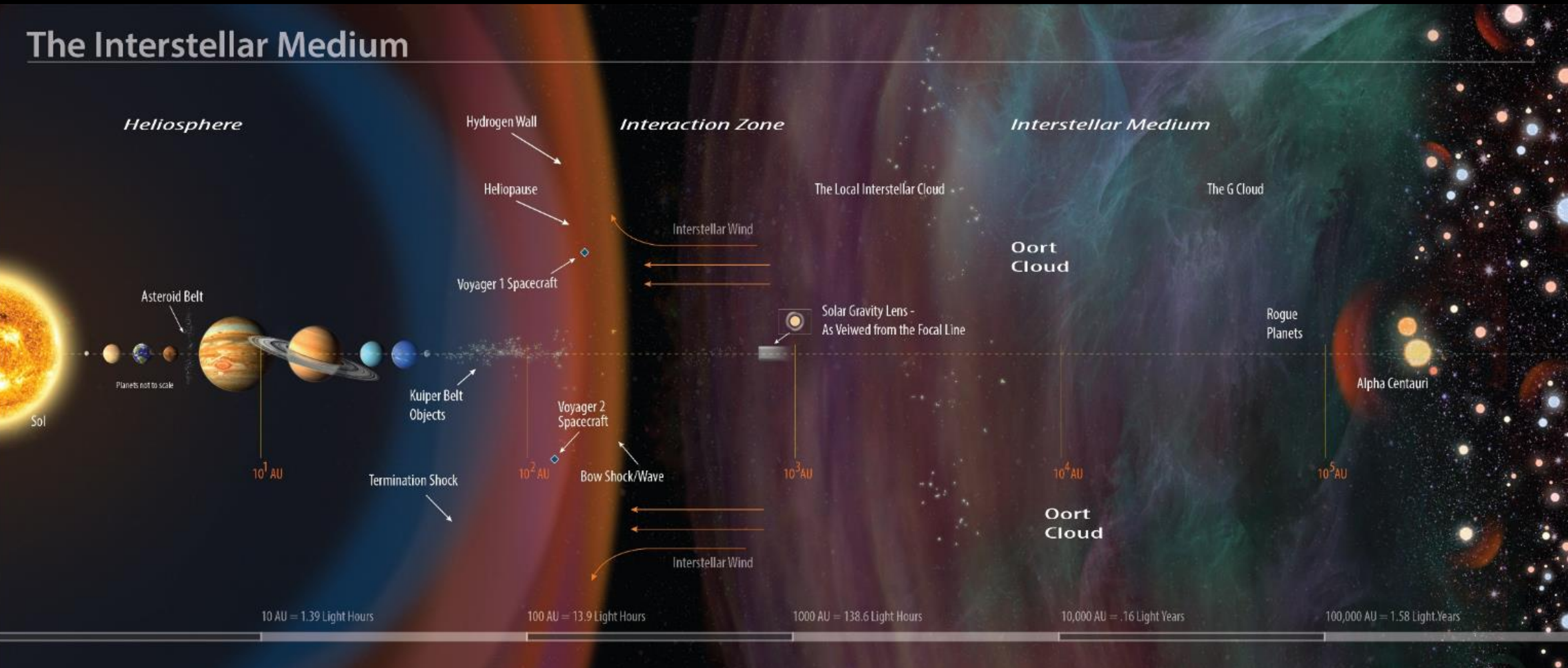
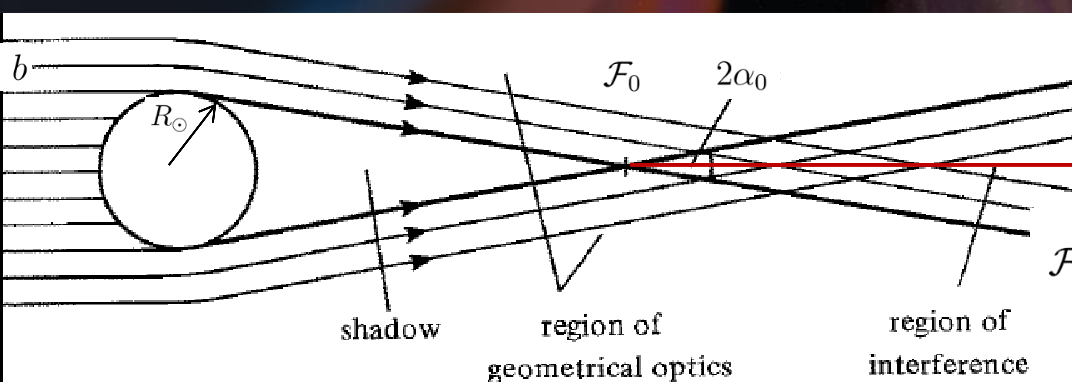
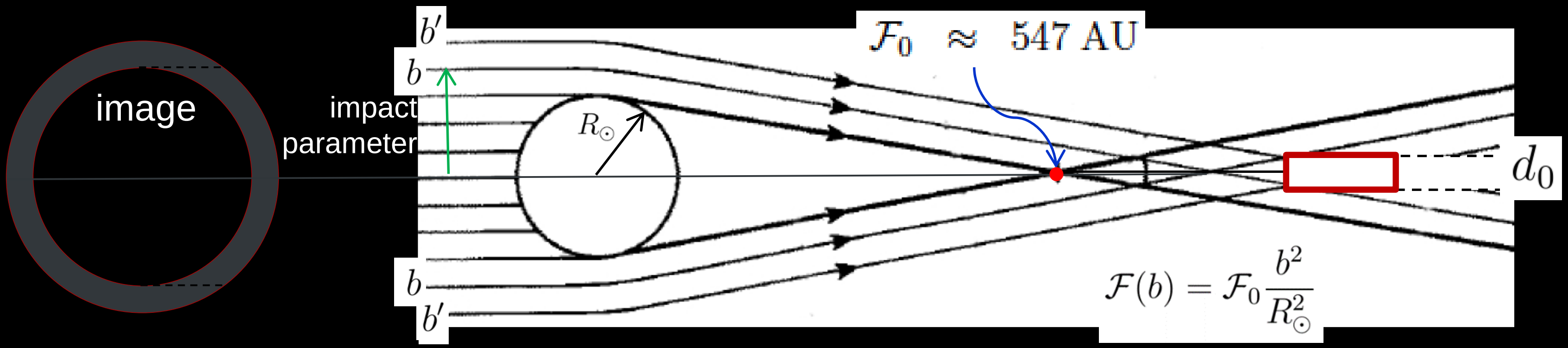




$$\alpha_0 = \frac{2r_g}{R_\odot} \approx 8.5\ \mu\text{rad} \quad \rightarrow \quad \alpha(b) = \alpha_0 \frac{R_\odot}{b}$$

$$\mathcal{F}_0 = \frac{R_\odot}{\alpha_0} = \frac{R_\odot^2}{2r_g} \approx 547\ \text{AU} \quad \rightarrow \quad \mathcal{F}(b) = \mathcal{F}_0 \frac{b^2}{R_\odot^2}$$

PROPERTIES OF THE SOLAR GRAVITY



- Important features of the SGL (for λ = 1 μm):
  - Major brightness magnification: a factor of 10^{11} (on the optical axis);
  - High angular resolution: ~0.5 nano-arcsec. A 1-m telescope at the SGL collects light from a ~(10km × 10km) spot on the surface of the planet, bringing this light to one 1-m size pixel in the image plane of the SGL;
  - Extremely narrow “pencil” beam: entire image of an exo-Earth (~13,000 km) at 100 l.y. is included within a cylinder with a diameter of ~1.3 km.
- Collecting area of a 1-m telescope at the SGL’s focus:
  - Telescope with diameter d_0 collects light with impact parameters $\delta b \simeq d_0$;
  - For a 1-m telescope at 750AU, the total collecting area is: 4.37×10^9 m^2, which is equivalent to a telescope with a diameter of ~80 km…

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TRANSFORMERS:
Building a Solar Power Infrastructure on the Moon

Adrian Stoica, Marco Quadrelli, Mitch Ingham, Leslie Tamppari, Karl Mitchell

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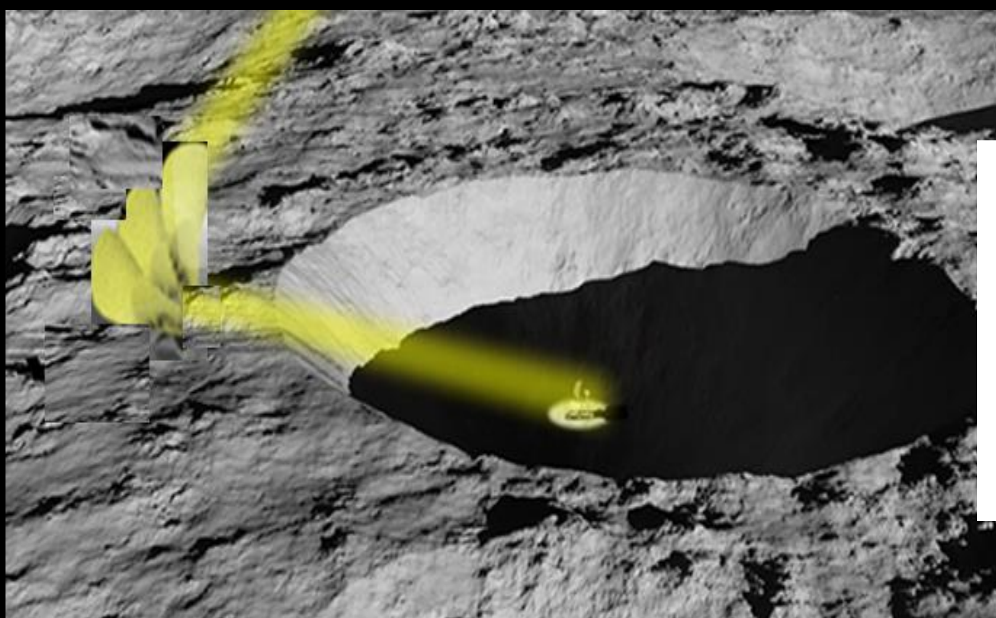
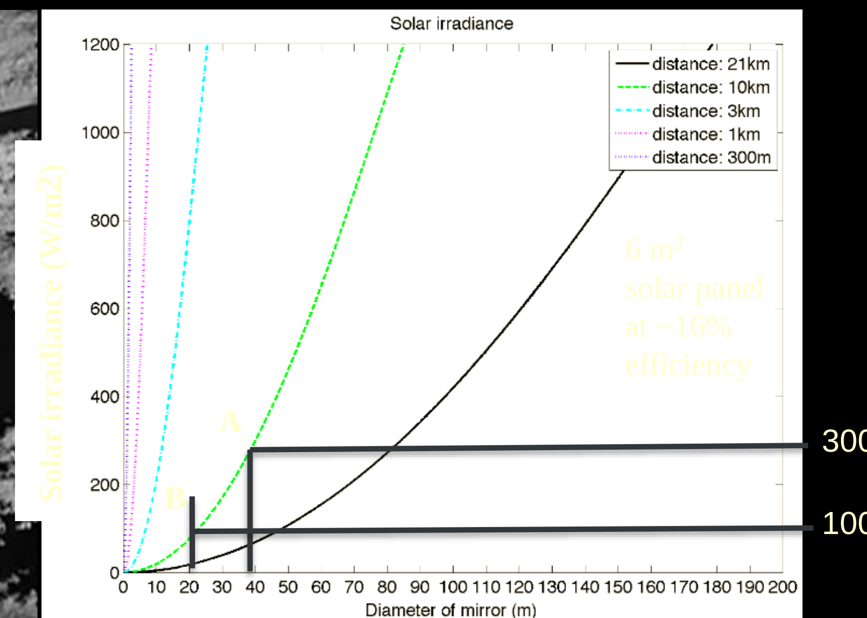
TRANSFORMERS:
Building a Solar Power Infrastructure on the Moon

TransFormers: - Shape Changing Robotic Reflectors

Transform an extreme environment (cold & dark) into a hospitable one. Placed on the rim of Shackleton Crater, TransFormers would enable robotic operations in permanently shaded regions at lunar poles, to extract water ice and further produce liquid hydrogen and oxygen (LH2/LO2) propellant.





A 40 m diameter TF ($1256 m^2$) is needed to provide ~300 W/m^2 of power at 10 km

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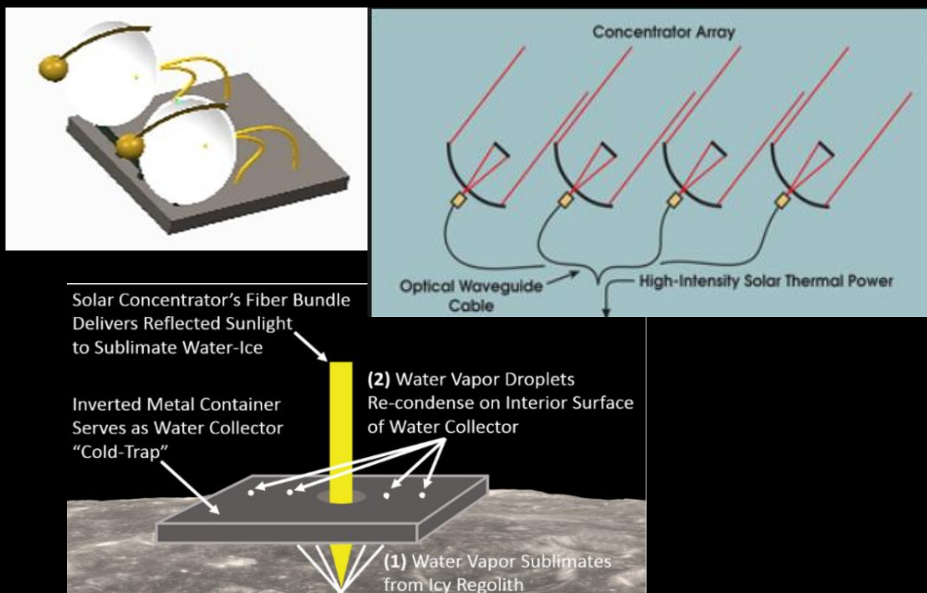
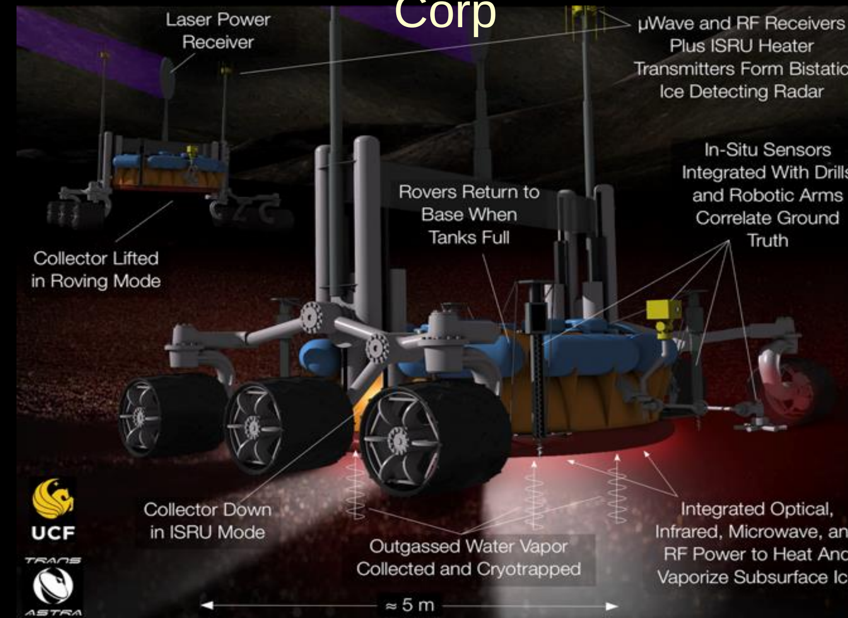
How to extract water from regolith? How much power is needed?

Kennedy Space Center concept



Radiant Gas Dynamic concept, TransAstra Corp



The energy needs to obtain 10 t of water per day:

- The energy (thermal) for water extraction: ranging from 0.54 MW (at 4.7 kJ/g, for 10% water in regolith) to 1.58 MW (at 13.8 kJ/g, for 1% water in regolith).
- The separation through electrolysis (at 18 kJ/g) would require ~2 MW (electric), i.e. ~6 MW solar received from TF assuming ~33% efficiency.

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