Technology Assessment of a Space Flight Demonstration LaserSail Propulsion

- KECK INSTITUTE FOR SPACE STUDIES (KISS) November 2015

Study Team Spun Off from the KISS Study: Exploring the Interstellar Medium (ISM)

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- Manan Arya, Calif. Institute of Technology
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Study Purpose and Rationale

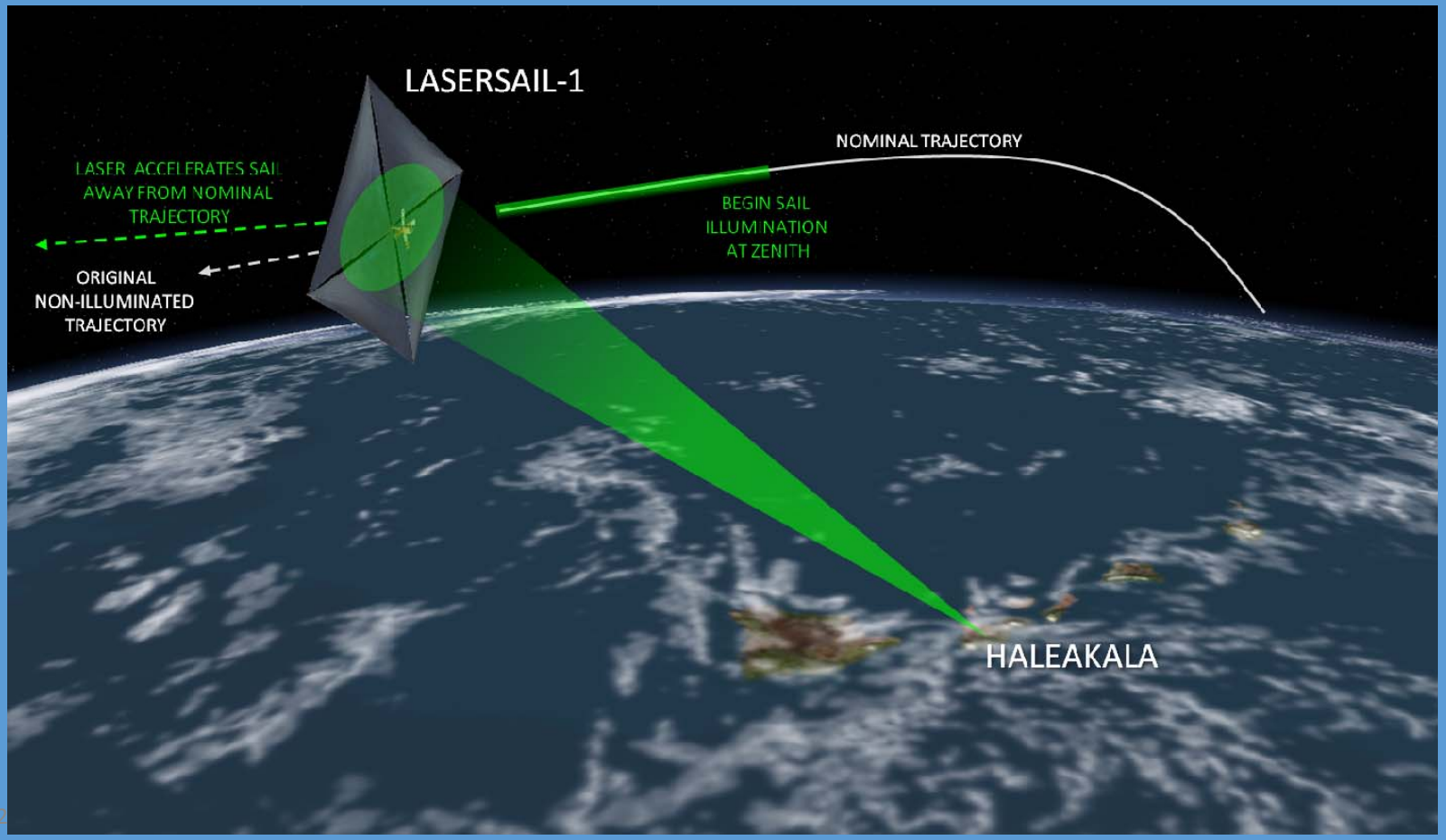
- Assess the feasibility of a low-cost and privately funded flight demonstration of laser propulsion of a spacesail
- Laser sailing is the only currently known interstellar flight technology
- Initial demonstration flight provides important first demonstration as foundation for more ambitious missions
- Evaluate feasibility of spacecraft requirements as a natural evolution of LightSail,and NEA Scout

Two Step Approach

- Ground-based laser illuminating LightSail
  - Firing a DoD laser from the ground has significant regulatory, political and public interest considerations. The scheduled 2016/17 flight of LightSail is an opportunity to work issues involved by going through all the appropriate and required administrative procedures with a specific flight schedule.
- Space-based laser in a smallsat illuminating a smaller LightSail derived nanosat/sail spacecraft
  - Two spacecraft formation is of current interest and study (including even the Prox LightSail mission) and formation flying concepts under study
  - Two recent NIAC studies show development of space-based lasers for CubeSats and other small spacecraft

Ground-Based Laser Demonstration CONOPS

(Concept of Operations)



D.Garber

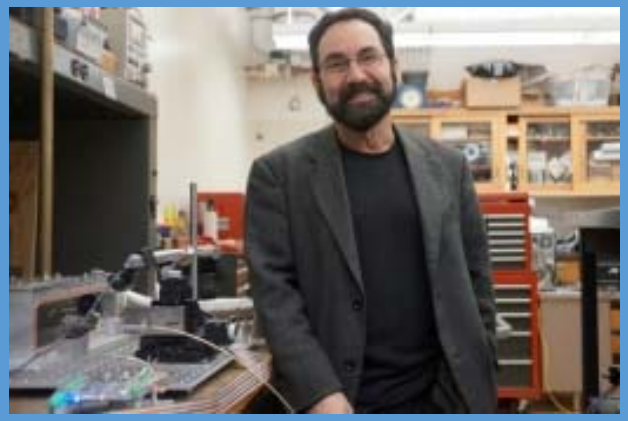
Ground-based Laser Opportunity:
the U.S. Army High Energy Laser Demonstrator

- Army interested in demonstration
- LightSail and Planetary Society also positive
- Space Act Agreements with NASA MSFC
- Laser can be taken to any advantageous location for LightSail's orbit
- BUT the planned upgrade from 10 kW to 50 kW now is delayed and under review
  - **Orbit effect may still be measurable**
  - **Operational experience will still be valuable**
  - Investigating Air Force's Starfire in Albuquerque as possible alternative

Space-based Laser Sail Flight Demonstration is Feasible

- Multi-hundred watt nanosat sized lasers exist in ground based laboratories ready for space qualification and flight testing

Prof. Phil Lubin, U.C. Santa Barbara



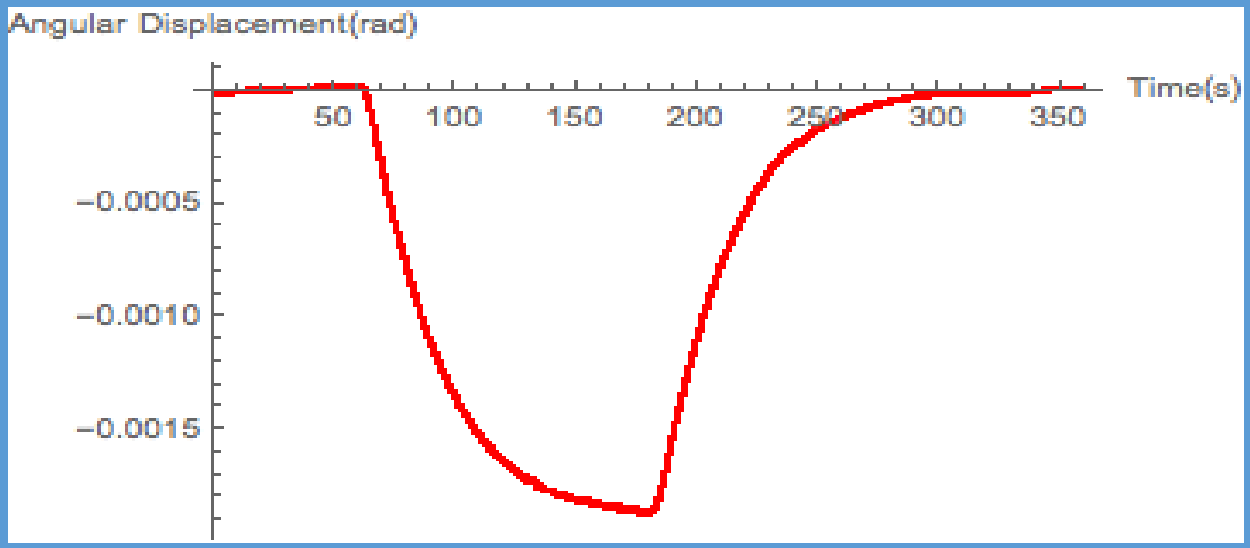
Dr. Young Bae, Y.K. Bae Corp.

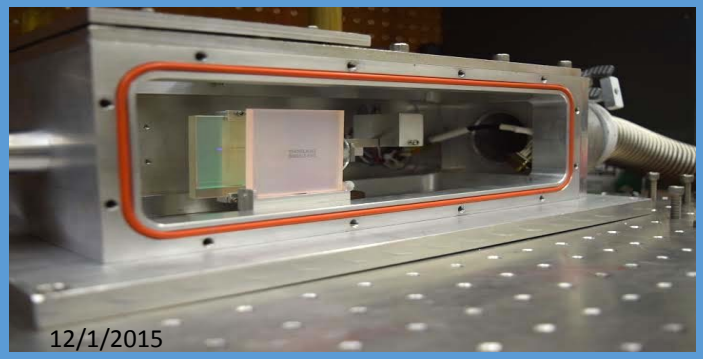
Laser Propulsion Demo (Young Bae)

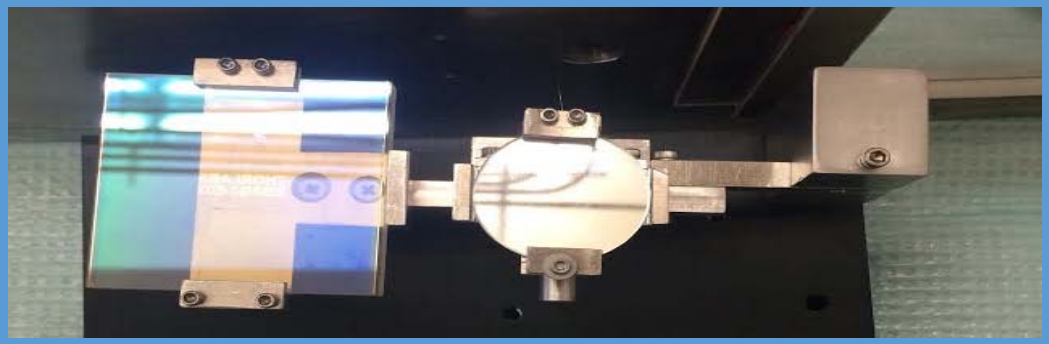
Laboratory propulsion of a CubeSat

Laser Propulsion Demo – UCSB

June 2015 - Lab test with 400 gram mass

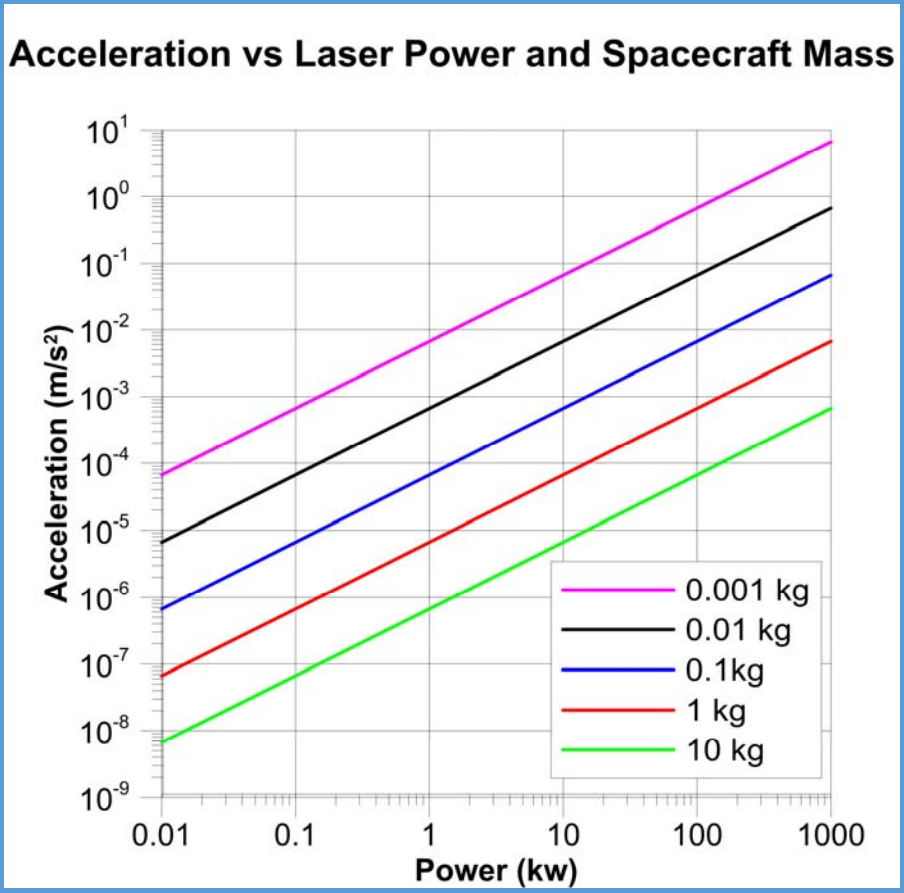






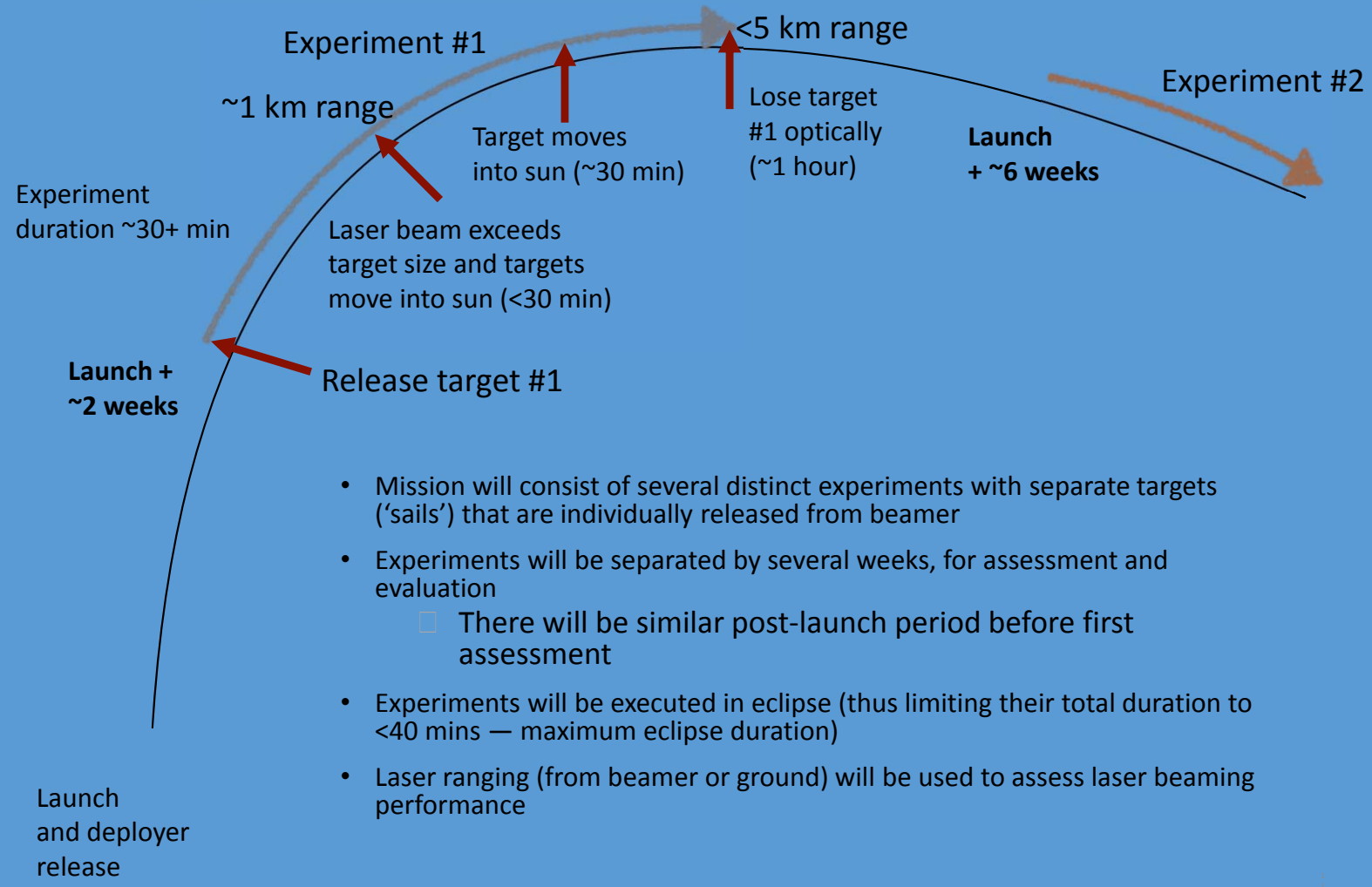
Laser propulsion

LightSail=6×10^{-5} мм/$с^2$



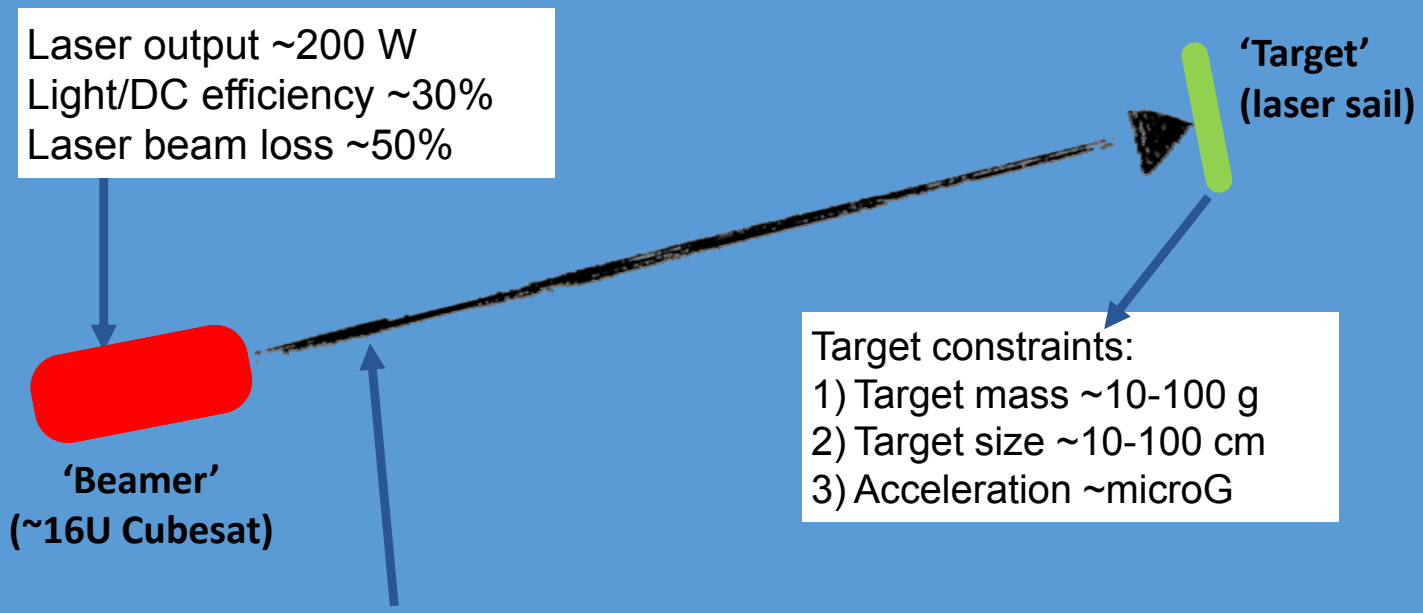
Phil Lubin, UCSB

Space Based Demonstration Conops



- Mission will consist of several distinct experiments with separate targets ('sails') that are individually released from beamer
- Experiments will be separated by several weeks, for assessment and evaluation
  - There will be similar post-launch period before first assessment
- Experiments will be executed in eclipse (thus limiting their total duration to <40 mins — maximum eclipse duration)
- Laser ranging (from beamer or ground) will be used to assess laser beaming performance

Laser Beaming Experiment Overview



Experiment <2000 sec
(completed in eclipse)
Battery mass ~8 kg

Spacecraft System Description — Initial Trade Study

- Laser source —three options:
  - industrial OEM unit (performance/risk compromise)
    - Fiber 1.06 µm laser with notional CW output ~200 W
    - IPG, Coherent, JDSU / Lumentum
  - Lubin
  - Bae
- Semi-custom optics relays fiber outputs to collimating telescope (reflective, off-axis, f/10, ~80-mm aperture)
  - Assuming modest performance (M2~2, ~50 µrad beam)
  - Focus adjustment (defocus) beam in proximity for heat flux management
- Electric power is easier problem
  - Battery — sole power source for beaming
  - ~1 kg battery supports 200 W laser for ~10 mins
  - Solar panels sized for housekeeping & battery trickle-charge (8+ TJC/UJC CICs)
- Thermal management is harder problem
  - Simple heat sink solution results in excessive mass
  - Phase Change Material solution is more practical solution

T. Svitek,
Stellar Exploration

Conclusions

- Powerful demo of interstellar propulsion potential
- Ground-based demo with LightSail is feasible, under consideration by TPS and NASA-MSFC
  - Acceleration is very small
  - Value will depend on cost
- Space-based mission concept feasible
  - Lasers form fitted to CubeSats
  - Adequate laser power
  - Photon recycling
  - CubeSat spacecraft
- 2 CubeSat Mission concept achievable
  - Precision pointing CubeSats
  - Low cost launch(es)
  - Simple mission operations
  - Costs same magnitude as LightSail
- Challenges with laser firing coordination, ops

Next Steps

- Conduct laser illumination experiment with LightSail to gain experience with coordination
  - Limit cost <$50K
- Assess overall costs and detailed risks: Detailed design of Lasercraft and lightweight sails
  - ~$200K to $400K
  - CubeSat spacecraft – Build Prototype or Engineering Model
  - Sail design
  - Laser system
  - Spacecraft power system
  - Mission operations
  - Mission safety assessment
  - TBD
- Develop program plan for implementation
- Build and fly 2-3 Lasersail spacecraft systems
  - TBD $5-10M