The Future of Human and Space Research: The Lagrange Communication Advanced Realtime Space-weather (LCARS) Array

A NASA Mission Concept

Presented by

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For the University of Kansas Department of Physics and Astronomy SpaceFest - 2025

In honor of the retirement of Prof. Thomas E. Cravens and Prof. Hume Feldman

LCARS Array website and Publications

https://LCARS.FTecs.com

Decadal White Paper

AGU 2022 Poster

AGU 2023 Poster

AGU 2024 Poster

LCARS Website

LCARS Array Vision Driving Question

In 2020 Dr. Nicola Fox held the NASA's Heliophysics 2050 Workshop's and asked the question:

What should Humanities Space Exploration and Expansion into the Solar System look like by the year 2050?

Assumptions:→ → → By the year 2050 there will be← ← ←

A Lunar Base with extensive communications capabilities

Humans on Mars – and since they won't be coming back, we call that a **Base**!

Significant expansion of NASAs Heliophysics System Observatory by sending multiple different spacecraft to the outer planets, to Mars, to the Asteroid belts, etc.

Interstellar Probe will be on its way and New Horizons will still be working

- (Note: Voyager unfortunately will be dead in the VLISM)

Why the **LCARS** Array – Now?

What are the problems of the present and near future that need to be addressed?

Data and Communications

- Manned Exploration of the solar system requires a large volume of data to be constantly streamed from all of the missions back to earth
- The Data volume by current (and to be flown) NASA missions has exploded exponentially heading into the 10's of TB / day
- Instrument capabilities are limited by bandwidth even with modern compression algorithms (lossless or lossy)
- High bandwidth Communications is very limited through Earth's atmosphere
- With some success, the recently tested Laser communications is also has issues due to need to maintain pointing

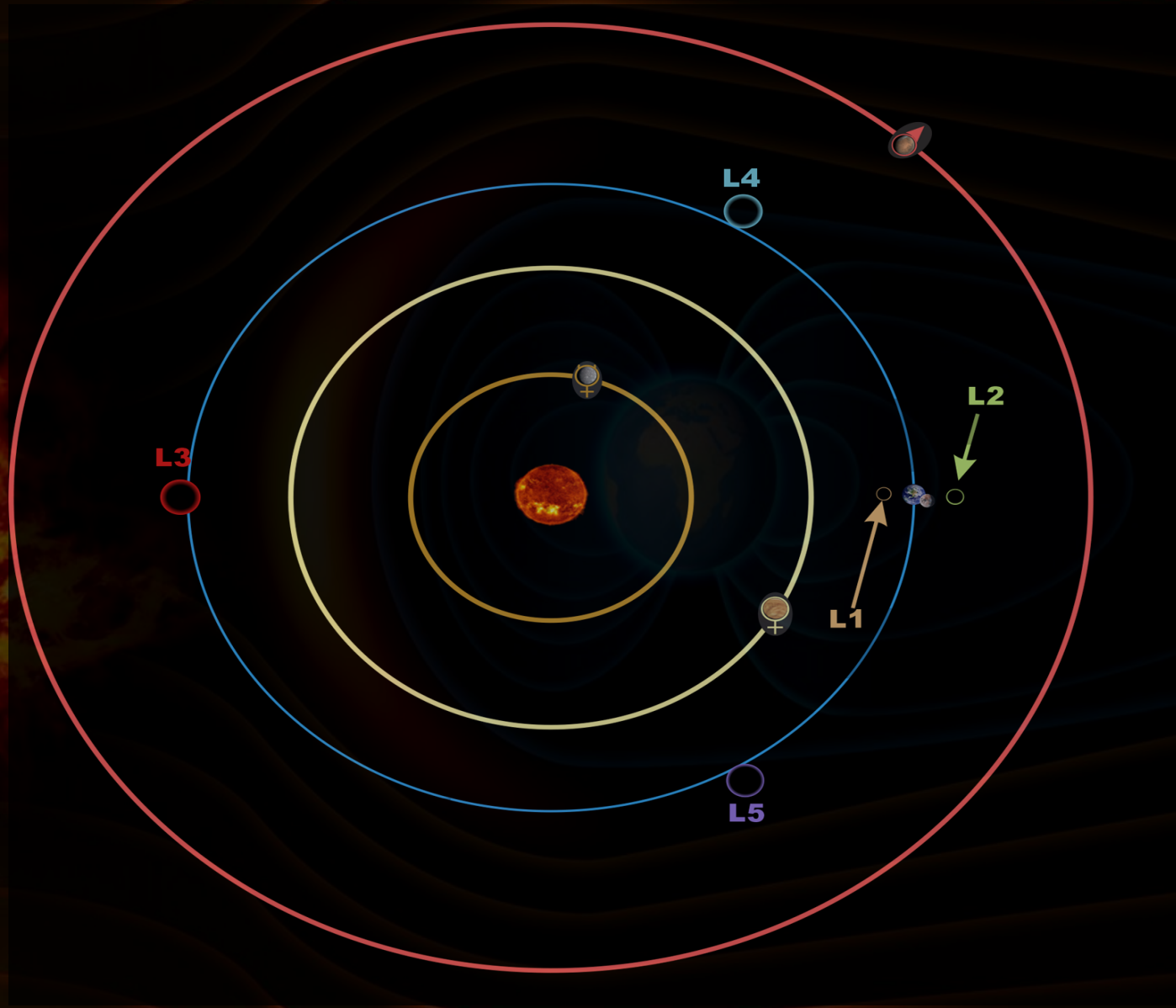
Space weather and Solar Science

- Understanding of The radiation environment in space otherwise called, Space weather, is critical to human exploration
- The number of historical and current missions in support of space weather research has allowed us a fundamental understanding of the overall impact that the Sun has on Earth's systems
  - The ACE, SOHO, WIND, STEREO A/B ,Solar Probe and Solar Orbiter missions providing discoveries beyond their original mission goals, but they can't see the "whole" sun all the time
- Space weather modeling accuracy demands a "whole" sun view allowing incremental and sometimes significant improvement in the ability to accurately predict times when Earth space assets are at risk as well as future Human assets in the solar system (Mars etc.)
- There is critical need for highly accurate space weather predictions for human presence on the Moon and Mars since both bodies spend significant amount of time in the Solar Wind exposed to Space Weather without a magnetic shield

- So…

The **LCARS** Array – the **Lagrange Points**

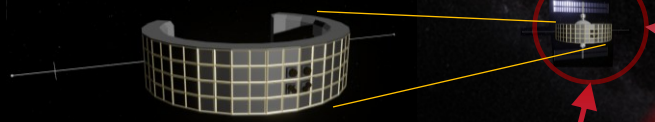
Lagrange Points for the Earth-Sun System showing the orbits of Mercury, Venus, Earth, and Mars



LCARS Vision

Space Platform (station) at each of the Earth-Sun Lagrange Points

L3 is behind the sun and can see L4 and L5, offers communications for missions obscured by sun



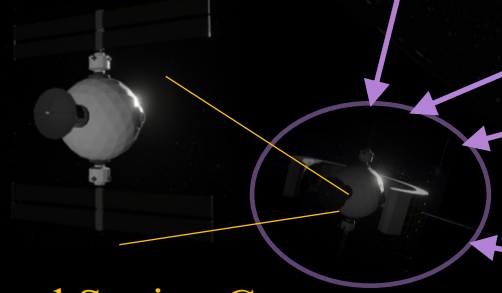
Each station includes Advanced modular multi-bay Solar and in-situ instruments with Ejectable and dock able sensors Observation Platform shields comms unit

The SOL-Network is an Interstation communications Network using Terahertz/Laser comms with AI based packet networking

L4 has unobstructed view of L3 and sits upstream of Space Weather flow along the Parker spiral

Idealized Lunar Communications

L1 is an upstream Space Weather Detector



L5 has unobstructed view of L3 and sits downstream of Space Weather flow along the Parker spiral

Earth-Lunar Comms

L2 is protected and offers redundant comms

Advanced Station Comms:
Multi-frequency
Multi-channel
Terahertz/Laser Network Comms
Advanced Gimbled Deep Space Dish

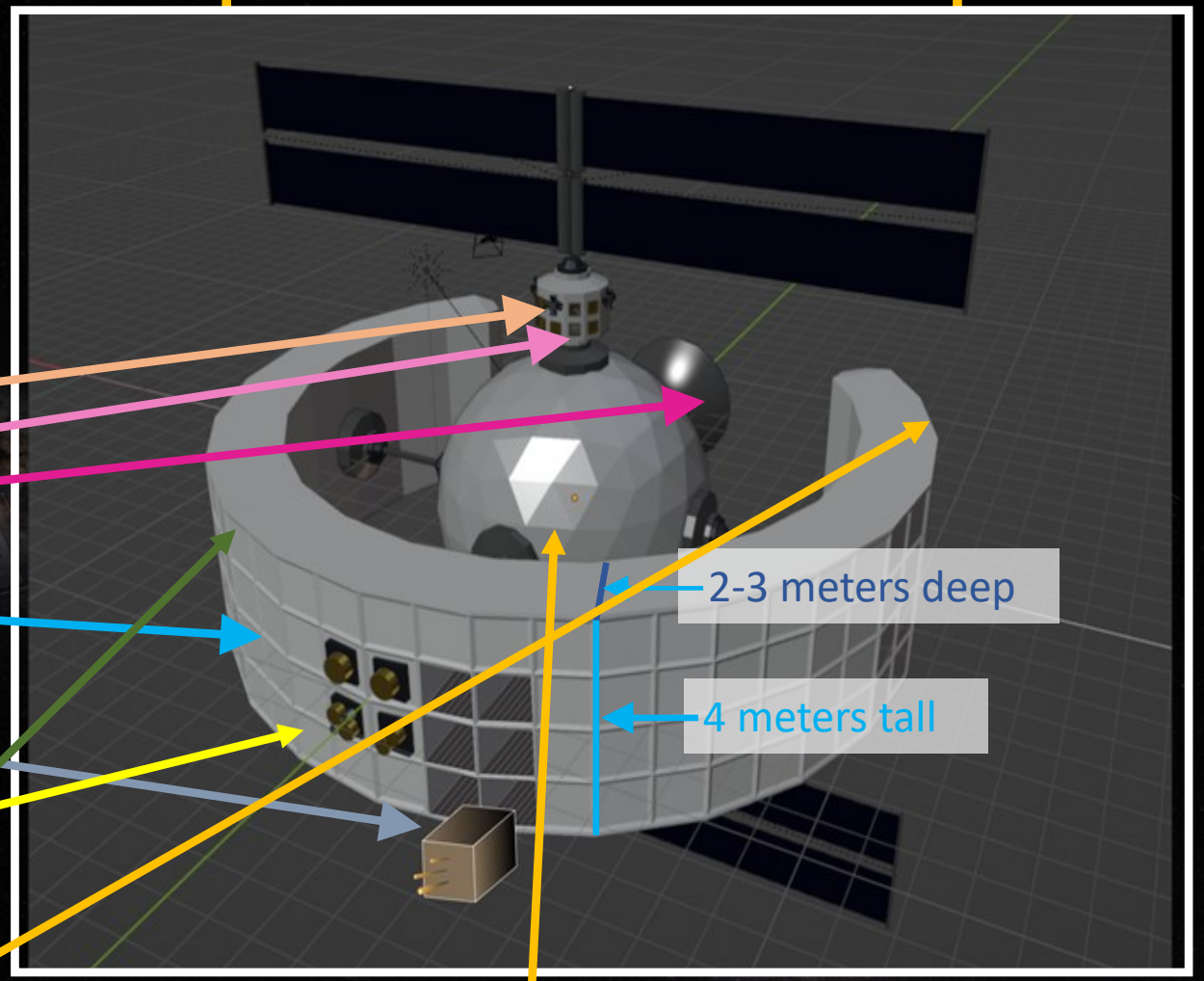
The **LCARS** Array – the Spacecraft Concept

The **LCARS** Array Spacecraft Concept
Novel Spacecraft Development
100 Year Mission Lifetime Goal

- Multi-Component Modular Spacecraft
- One or more transport rockets to units'
- Station Keeping engine at final destination
- Modular Spacecraft Design with Self Assembly capability

Separate Communications and Sensor Sections

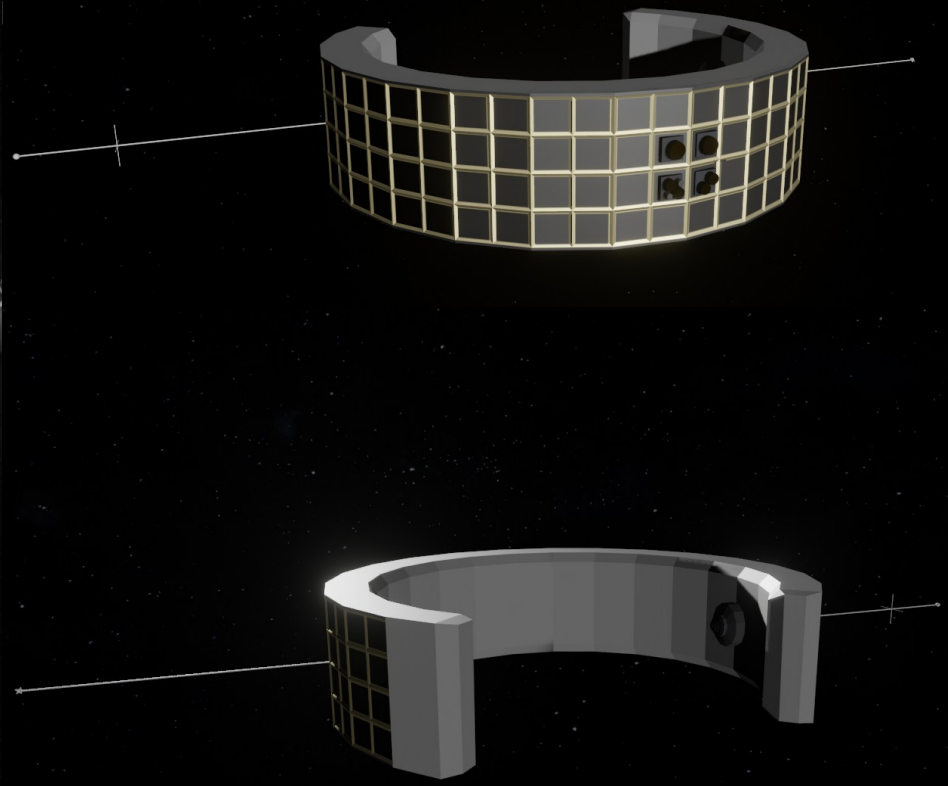
- Communications Section
  - Inter-SC COMM (Laser +Terahertz)
  - Multichannel/Multifrequency Radio Comms
  - Gimbled Deep Space Communications
- Sensor Section
  - Current Sizing: 4 m tall x 2-3 m deep
  - Sensor Section SHIELDS the Communications Array!
  - Modular Instrument Bays, 4 m tall x 28 m
    - 1 m^2 sections divided as 1 dm^2 units
    - Power and Data per unit
    - **Up to 100 units per section and 2800 total units**
  - Direct Solar Telescopes with continuous recording
  - In-Situ Solar Wind Instruments with continuous recording scattered throughout the available bays
  - Stellar telescopes instruments on available side and rear looking bays



The **LCARS** Array – the Instrument Deck

The **LCARS** Array Spacecraft Concept

- Instrument Section
  - Modular Instrument Bays
  - Direct Solar Telescopes with continuous recording
    - Photospheric Imager
    - Solar Magnetograms
    - Coronal Imager
    - Coronal Spectrogram
    - etc.
  - In-Situ Solar Wind Instruments with continuous recording
    - Cosmic Ray Particle Detectors
    - Plasma Sensors, e.g.
      - Top-Hat Detectors
      - Langmuir Probes
    - Magnetic Field Antennae and Internal Sensors
    - Electric Field Antennae and Spacecraft Charging Sensors
  - Rear facing internal outward facing elements provide space for background measurements to calibrate other instruments



The **LCARS** Array – Technology

The **LCARS** Technology Development

- Novel Communication Technologies
  - Inter-SC COMM (Laser +Terahertz Gimbled)
  - Autonomous Networking
- Hardware:
  - Terahertz and Laser Communications Systems
  - Gimbled Deep Space Communications Dish
  - Multichannel/Multifrequency Radio Comms
- Protocols:
  - Interplanetary Communication Protocols (up to 18 minute packet delays)
  - Adaptive and Predictive AI protocol evolution
- Adaptive Deep Space Dish Capabilities:
  - Gimbled pointing
  - Central receiver
  - Lightweight Dish materials (e.g. Mylar)
  - Deployable and Retractable Dish
  - Variable Dish Surface Area w/ R <= 35m
- Novel Spacecraft Technologies
  - Multi-Component Modular Spacecraft
  - One or more transport rockets to final destination
  - Station Keeping engine at final destination
  - Modular Spacecraft Design with Self Assembly capability
- Novel Software Systems
  - Self-writing (AI) Adaptive Software Systems
  - Self-healing (AI) Redundant Software Systems
  - Adaptive / Predictive Data Analytics – e.g. Predictive Decision Making onboard each Space station

The **LCARS** Technology Development

- Novel Sensor Module Technologies
  - Modular Instrument Bays
  - Self-Docking Modules
  - Spacecraft ejection of defective modules
- Data System Technologies
  - Large Redundant Data System
  - Photonic or Quantum Storage Technologies
  - Large Redundant Data Systems
  - Self-Healing Hardened Systems
  - Storage Module Ejection and Replacement
  - Autonomic Data Management
- Novel Power System Capability
  - Solar Panels used for minimum power requirements
  - Replaceable Solar Arrays and Fuel Cells
  - Embedded Fuel Cell Array used for Operations
    - Primary power for Comms
- Power provided per Bay Unit for experiments
  - Each bay unit provides Vmax power
  - Coupled bays provide N*Vmax power

LCARS Array – The Future

LCARS Array – Into the Future

Additional LCARS Array can be deployed at other Lagrange points.

1) The Earth Moon Lagrange points (trial)

2) The Mars Sun Lagrange points
   - Different orbital cadence
   - Provides the capability to significantly enhance the overall SOL-Network
   - The orbital period of this LCARS Array would be different providing additional continuous coverage of deep space assets

3) What about the Mercury Sun Lagrange Points
   - This would give an LCARS Array Solar Observatory at 0.3 AU (near the current Solar Orbiter distance)

   The enhancement to direct and immediate measurement of the in-situ Space Weather would greatly increase the predictive powers of the Space Weather Modeling systems

4) What about Jupiter, Saturn, Uranus, or Neptune?