An L5 Mission Concept for Compelling New Space Weather Science

RESCO (China)
REal-time Sun-earth Connections Observatory

INSTANT (Europe)
INvestigation of Solar-Terrestrial Associated Natural Threats

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Overview: CMEs and space weather

- Coronal mass ejections (CMEs) are large expulsions of plasma and magnetic field from the solar corona and drivers of major space weather effects;

- Estimated cost of an extreme CME could reach up to a trillion dollars with a potential recovery time of 4 - 10 years.
Overview: Motivation

• A number of spacecraft making routine remote-sensing and in-situ observations (such as SOHO, Wind and ACE) are already at L1, and are expected to operate there in the next 5-10 (or more) years;

• SDO, although not at L1, has a function similar to SOHO, and its extraordinary capability cannot be exceeded by a similar spacecraft near Earth;

• We must go away from the Sun-Earth line to cover the whole Sun-Earth space (STEREO).
Mission concept: RESCO

REal-time Sun-earth Connections Observatory

- A dedicated spacecraft at L5 to make combined remote-sensing and in-situ observations of the whole Sun-Earth space.
- Primary objective:
  Understand nature and Sun-to-Earth propagation of solar wind transients.
- Suggested payload:
  - EUV imager (15 kg, optional);
  - Coronagraph (20 kg);
  - Heliospheric imager (15 kg);
  - Magnetometer (3 kg);
  - Solar wind plasma detector (5 kg).

Scientific objectives

• Investigate the Sun-to-Earth propagation of solar wind transients (including CMEs and CIRs) with unprecedented high-cadence, wide-angle imaging observations;

• Understand the nature of solar wind transients by connecting imaging observations with in-situ measurements;

• Determine the magnetic field magnitude and orientation of Earth-directed CMEs for the first time;

• Explore the advantages for space weather forecasting provided by the L5/L4 vantage points.
• Understand the physical mechanisms that govern the Sun-to-Earth propagation of solar wind transients;

• Understand how solar wind transients interact with the ambient corona and heliosphere;

• Understand how solar wind transients interact with other coronal and solar wind structures;

• Develop a practical capability for space weather forecasting.
Nature of solar wind transients

- Investigate how wide-angle imaging observations connect with in-situ signatures;
- Disentangle the structures of solar wind transients including CMEs and CIRs;
- Understand the physical nature of solar wind transients.
First ever capability of determining CME B field

- CME magnetic field is a key element in space weather but so far elusive;
- Novel Lyman-alpha measurements to determine the magnetic field magnitude and orientation through the Hanle effect;
- The L5 location is ideal for early determination of magnetic structure of Earth-directed CMEs.
Space weather advantages at L5/L4

Gravitationally stable, and always able to monitor the Sun-Earth line

Advance warning of active regions and coronal holes that will soon rotate to Earth view

CMEs can be imaged all the way to the Earth with projection minimized and structures discerned

Advance in situ measurements of CIRs before they arrive at Earth
## Suggested payload

<table>
<thead>
<tr>
<th>Science objective</th>
<th>Required measurements</th>
</tr>
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<tbody>
<tr>
<td>Investigate the Sun-to-Earth propagation of solar wind transients</td>
<td>wide-angle white light, EUV (optional)</td>
</tr>
<tr>
<td>Understand the nature of solar wind transients by connecting imaging observations</td>
<td>wide-angle white light, in situ plasma and magnetic field</td>
</tr>
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<td>with in-situ measurements</td>
<td></td>
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<tr>
<td>Determine the magnetic field magnitude and orientation of Earth-directed CMEs for</td>
<td>Lyman-alpha polarization measurements</td>
</tr>
<tr>
<td>the first time</td>
<td></td>
</tr>
<tr>
<td>Explore the advantages for space weather forecasting provided by the L5/L4 vantage</td>
<td>wide-angle white light, in situ plasma and magnetic field, EUV (optional)</td>
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<td>points</td>
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### Suggested payload

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Mass (kg)</th>
<th>Power (W)</th>
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<tbody>
<tr>
<td>EUV Imager (optional)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Lyman-alpha Coronagraph</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Heliospheric Imager</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Solar Wind Plasma Detector</td>
<td>5</td>
<td>3</td>
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<tr>
<td>Fluxgate Magnetometer</td>
<td>3</td>
<td>2</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>58</strong></td>
<td><strong>50</strong></td>
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</table>

- This concept can satisfy the technical constraints (spacecraft mass ≤ 250 kg, payload mass ≤ 60 kg and power ~ 50 W);
- It requires a propulsion module to station the spacecraft at L5, and the launcher is envisaged as Long March 2 or Soyuz.
STEREO, launched in Oct 26, 2006, is twin spacecraft off the Sun-Earth line.

The two spacecraft drift away from Earth, so STEREO doesn’t provide a fixed vantage point.

We have been on the STEREO team for years and familiar with both the science and instrumentation.

Four instrument packages:

- **SECCHI** (image a CME from its birth in the corona all the way to the Earth);
- **IMPACT** (measure in situ particles and magnetic field);
- **PLASTIC** (measure in situ solar wind plasma and minor ions);
- **SWAVES** (measure radio emissions).
Similar concepts in Europe and US

- An L5 mission is a key proposal in US Decadal Survey;
- The mission concept was studied at the Mission Design Laboratory, NASA GSFC;
- A straw man L5 mission was formulated, EASCO (Gopalswamy et al. 2011);
- Also see INSTANT poster by Benoit Lavraud.

### Earth-Affecting Solar Causes Observatory (EASCO)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Mass (kg)</th>
<th>Power (W)</th>
<th>Data Rate (kbps)</th>
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<tr>
<td>Total</td>
<td>138</td>
<td>194</td>
<td>90</td>
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</table>
Summary

• L5 has various advantages, which can greatly advance space weather science and forecasting. Many countries are pushing for an L5 mission, and China/ESA can be the first!

• The concept we propose will address compelling new science and develop practical space weather capabilities under the technical and programmatic constraints.

• As a crucial and popular idea, the L5 concept would allow wide collaborations between CAS and ESA on both science and instrumentation in solar physics, space physics and space weather.

Thank you!