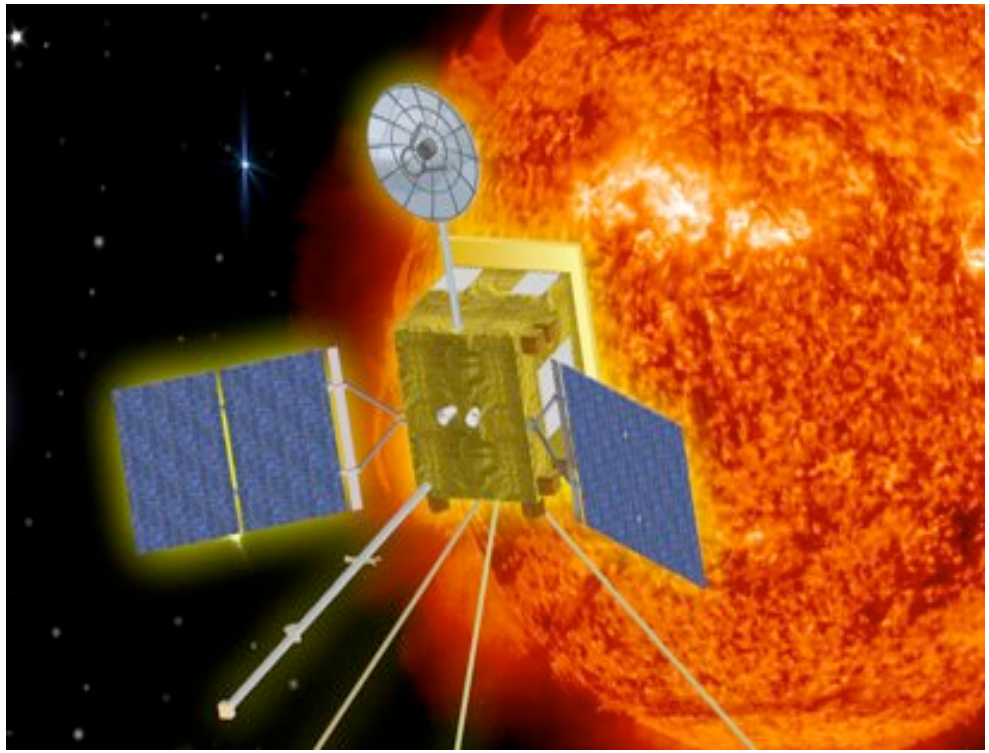
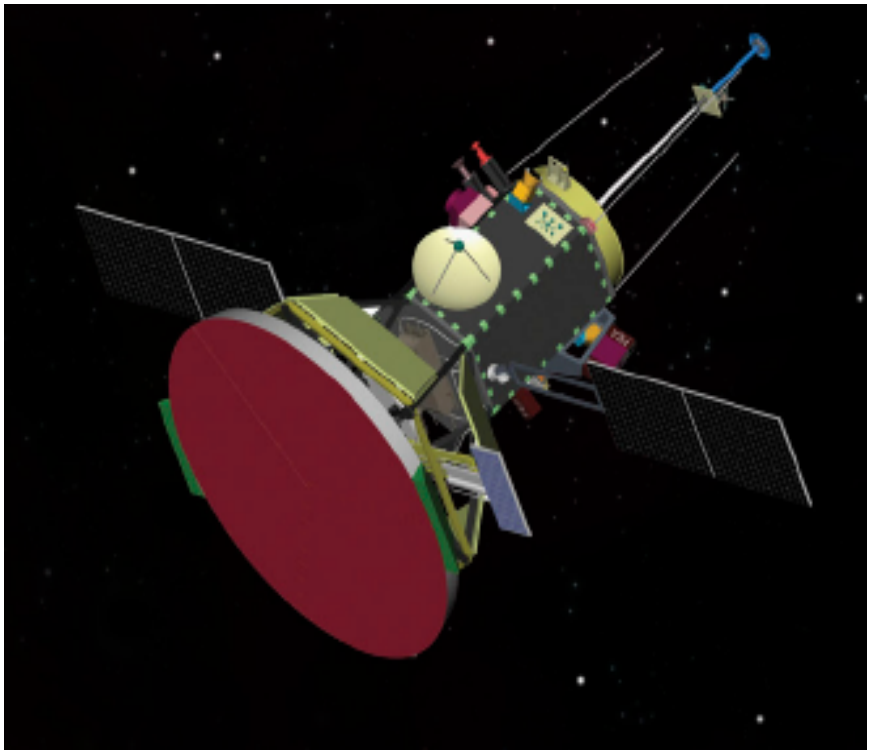
Lucie Green & Michelle Murray
Solar Group Meeting (25/03/09)

UCL

Synergies of Orbiter & Probe+





The legacy

2000 Solar Orbiter first selected as ESA mission

2005 Solar Probe proposed

2006 Solar Sentinels proposed
Solar Orbiter statement of intent

2007 Solar Orbiter announcement of opportunity

2008 Sentinels Lite proposed (revised Solar Sentinels)
HELEX (Solar Orbiter & Sentinels Lite) proposed
Solar Probe+ proposed (revised Solar Probe)
Sentinels Lite dropped (& therefore HELEX dropped?)
Solar Orbiter enters ESA's Cosmic Visions

The legacy

2000 Solar Orbiter first selected as ESA mission

2005 Solar Probe proposed

2006

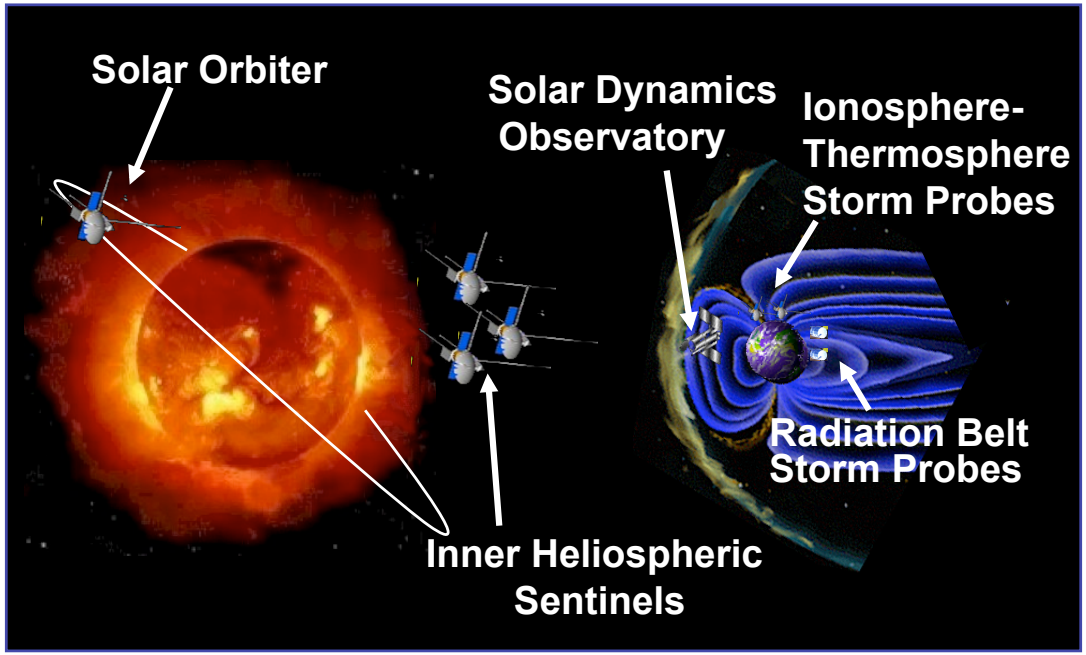
Can Probe+ replace Sentinels in the HELEX package and achieve the same (or more!) science?

2007

2008 Sentinels Lite proposed (revised Solar Sentinels)
HELEX (Solar Orbiter & Sentinels Lite) proposed
Solar Probe+ proposed (revised Solar Probe)
Sentinels Lite dropped (& therefore HELEX dropped?)
Solar Orbiter enters ESA's Cosmic Visions

HELEX

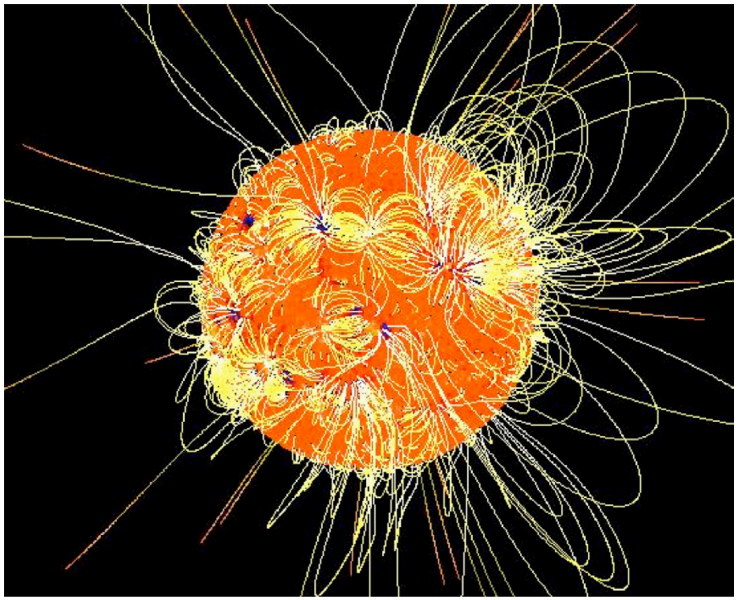
- Heliophysics Explorers (HELEX)
- Consists of Solar Orbiter and Sentinels missions
- ESA-NASA joint science programme
- Greater science productivity through joining missions
- 2015 - Orbiter launch
- 2017 - Sentinels launch

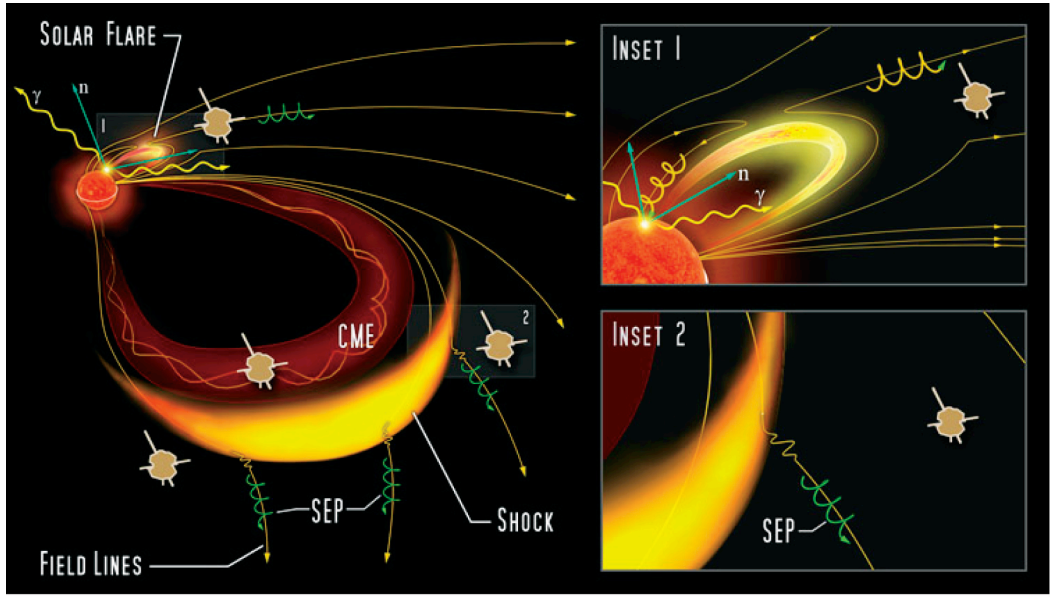


HELEX science questions

3 overarching questions:

- What are the origins of the solar wind and heliospheric magnetic field?
- What are the sources, acceleration mechanisms, and transport processes of SEPs?
- How do CMEs evolve in the inner heliosphere?

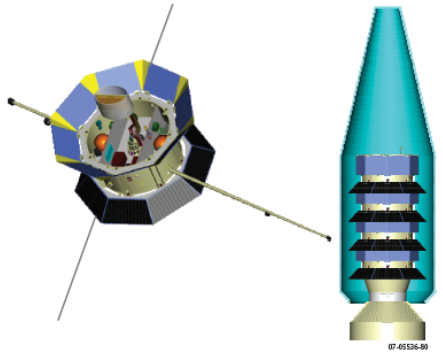




Contributions from each mission

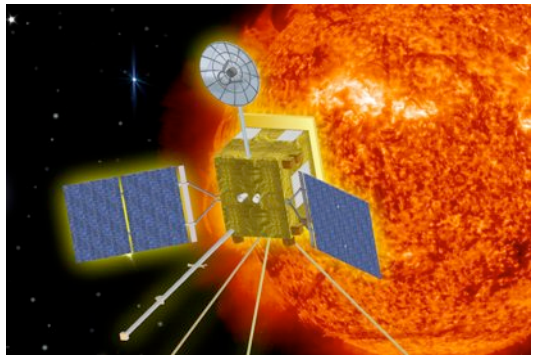
Sentinels:

- In situ plasma measurements
- From 4 locations in ecliptic (multipoint measurements)



Solar Orbiter:

- Remote sensing
- 5th Sentinel (in situ), out of ecliptic plane

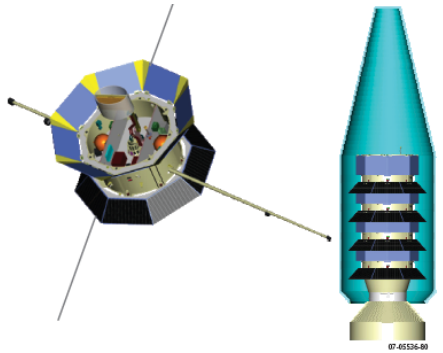


They need each other to get the most from the science.

Contributions from each mission

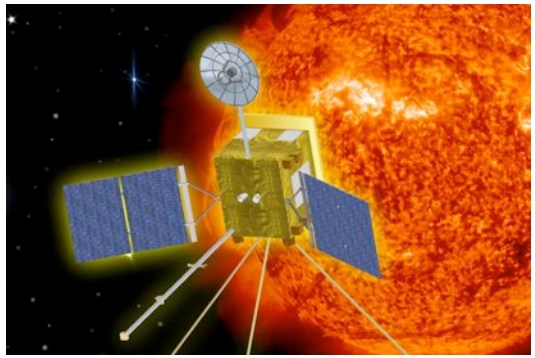
Sentinels:

- In situ plasma measurements
- From 4 locations in ecliptic (multipoint measurements)



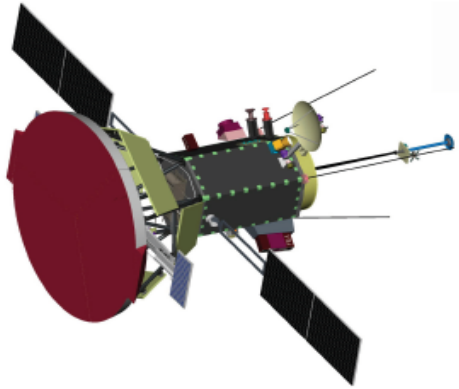
Solar Orbiter:

- Remote sensing
- 5th Sentinel (in situ), out of ecliptic plane



They need each other to get the most from the science.

But Sentinels has been scrapped & is replaced by single spacecraft Probe+



Sentinels vs. Probe+: Instruments

Sentinels

- Solar wind electrons
- Solar wind ion analsyer
- Suprathermal low energy ion composition analyser
- High energy ion composition analyser
- Solar wind composition analyser
- Energetic particle (electrons and protons) instrument
- Magnetometer (AC & DC)
- Neutron spectrometer
- X-ray & gamma ray spectrometer
- Radio wave instrument

Sentinels vs. Probe+: Instruments

Sentinels

- Solar wind electrons
- Solar wind ion analsyer
- Suprathermal low energy ion composition analyser
- High energy ion composition analyser
- Solar wind composition analyser
- Energetic particle (electrons and protons) instrument
- Magnetometer (AC & DC)
- Neutron spectrometer
- X-ray & gamma ray spectrometer
- Radio wave instrument

Probe+

- 2 fast electron analysers
- Fast ion analyser
- Ion composition analyser
- Energetic particle instrument
- Magnetometer (DC)
- Neutron gamma ray spectrometer
- Plasma wave instrument
- Coronal dust detector
- White light coronagraph

Sentinels vs. Probe+: Instruments

Sentinels

- Solar wind electrons
- Solar wind ion analsyer
- Suprathermal low energy ion composition analyser
- High energy ion composition analyser
- Solar wind composition analyser
- Energetic particle (electrons and protons) instrument
- Magnetometer (AC & DC)
- Neutron spectrometer
- X-ray & gamma ray spectrometer
- Radio wave instrument

Probe+

- 2 fast electron analysers
- Fast ion analyser
- Ion composition analyser
- Energetic particle instrument
- Magnetometer (DC)
- Neutron gamma ray spectrometer
- Plasma wave instrument
- Coronal dust detector
- White light coronagraph

These instruments are similar to in situ package on Solar Orbiter

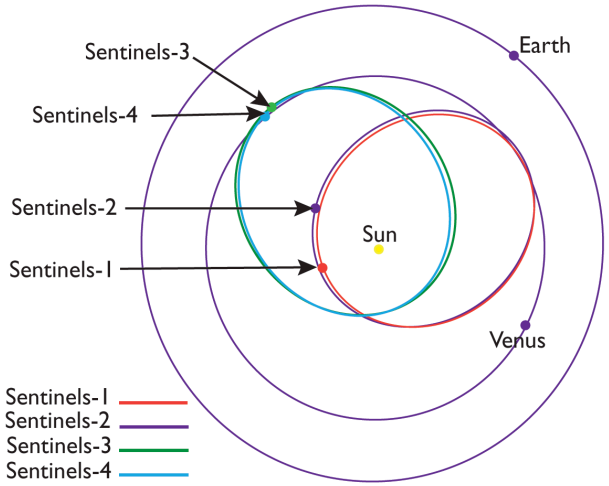
Sentinels vs. Probe+: Orbits

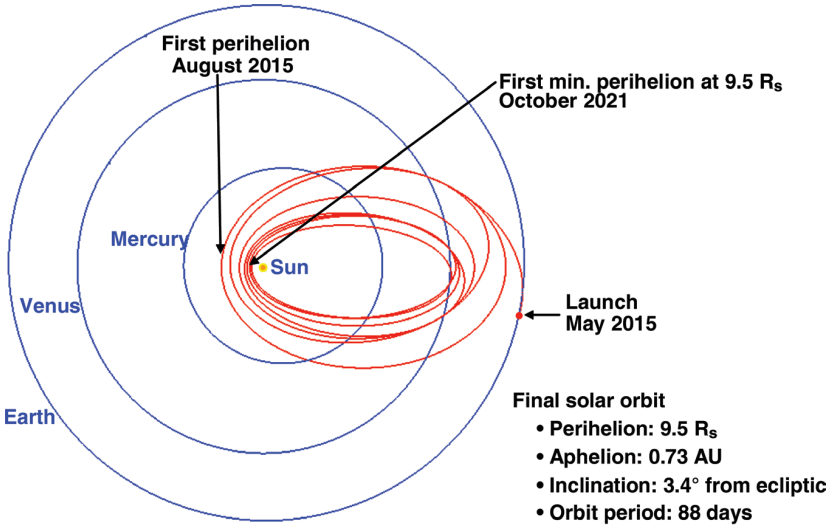
Sentinels

- Perihelion: 0.25 AU
- Aphelion: 0.76 AU
- Period: ?
- Mission lifetime: minimum 3 yrs
- In ecliptic plane

Probe+

- Perihelion: >0.05 AU
- Aphelion: >0.73 AU
- Period: 88 -150 days
- Mission lifetime: 6.9 yrs
- In ecliptic plane





Sentinels vs. Probe+: Orbits

Sentinels

- Perihelion: 0.25 AU
- Aphelion: 0.76 AU
- Period: ?
- Mission lifetime: minimum 3 yrs
- In ecliptic plane

Probe+

- Perihelion: >0.05 AU
- Aphelion: >0.73 AU
- Period: 88 -150 days
- Mission lifetime: 6.9 yrs
- In ecliptic plane

Sentinels and Probe+ are similar in instruments and orbits

So, Probe+ seems like a good substitute for Sentinels in the HELEX package

Can original HELEX science be done?

Some of the science goals required multipoint in situ measurements, so will depend on the relative positions/co-alignment of Solar Orbiter and Probe+ (indicated by *)

- **Origins of solar wind streams**
  - Requires multipoint obs. to map magnetic field back to surface and detect variations with longitude & radii - *possibly
  - Tracing solar wind packets to source - *possibly
  - Requires multipoint obs. to see fluctuations and fine structure in solar wind & determine origin - *possibly
- **Sources & acceleration of SEPs**
  - In situ time varying composition of suprathermals - yes
  - Multipoint obs. of CME shock region - *possibly
  - Shock vs. loop acceleration requires proximity to source and multipoint? - *possibly
- **Evolution of CMEs**
  - Multipoint obs. of plasma and magnetic properties include coronagraph (for ICME topology) - *no
  - Evolution of heliospheric flux content, in situ up-close obs. required – yes
  - Multipoint obs. of plasma and mag. properties for CME (connect to Sun) - *possibly
  - Shock formation & temporal properties, requires proximity, magnetograms & in situ - yes

Orbiter science: can probe help?

- Why does the Sun vary and how does the solar dynamo work? (map and describe the rotation, meridional flows, and magnetic topology near the Sun's poles.) Yes, measure temporal heliospheric flux evolution.

- What are the fundamental physical processes at work in the solar atmosphere and in the heliosphere? (reveal the flow of energy through the coupled layers of the solar atmosphere, e.g. to identify the small-scale sources of coronal heating and solar wind acceleration. Study wave-particle interactions in the solar wind. Understand the nature of dynamic events such as flares and CMEs and their effects on space weather.) Yes, Probe+ fills 0.05 - 0.25 AU gap & increases data set & gives extra viewpoint.

- What are the links between the magnetic field dominated regime in the solar corona and the particle dominated regime in the heliosphere? Yes, Probe+ fills 0.05 - 0.25 AU gap & increases data set & gives extra viewpoint.

Probe+ science: can Orbiter help?

- What is structure and dynamics of the magnetic field at the source of the solar wind? (magnetic field & solar wind expansion, slow solar wind source, role of plumes)
- What is the flow of energy that heats the corona and accelerates the solar wind?
- What mechanisms accelerate and transport energetic particles?
- What is the dust environment and how does it effect the inner heliosphere?

- Yes, remote sensing is vital! Multi-wavelength and magnetic field data is crucial.
- Orbiter starts to make Probe+ a multipoint mission!