ESA Space Weather Workshop

ALCATEL/LPCE Consortium

System Scenarios and Pilot Projects

ESTEC-Noordwijk, December 18th, 2001

ESA Study for SPACE WEATHER PROGRAMME

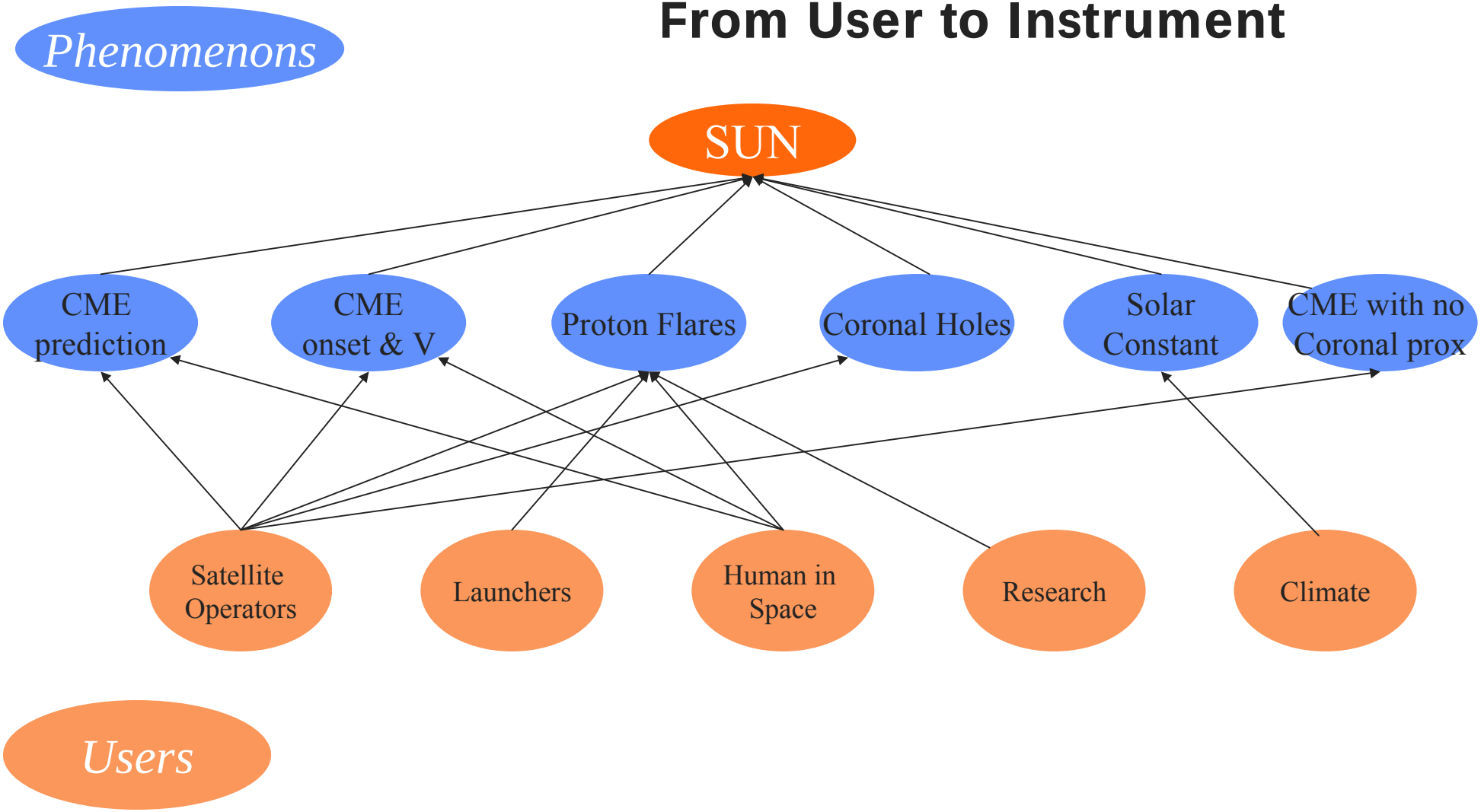
SYSTEM SCENARIOS (1/3)

- Rationale of SYSTEM SCENARIOS _1
  - Based on Space Instruments review & selection (MSSL Tasks)
  - Based on Ground Segment review and selection (LPSH + LPG Tasks)
  - Based on Space Segment definition (ALCATEL Space)
    - **Orbits definition**
    - **Trade-offs on Data Circulation => Continuous and Real-time constraint**
    - **Definition of most critical Satellites**
  - Targeting different levels of performances wrt User 's Needs fulfillment

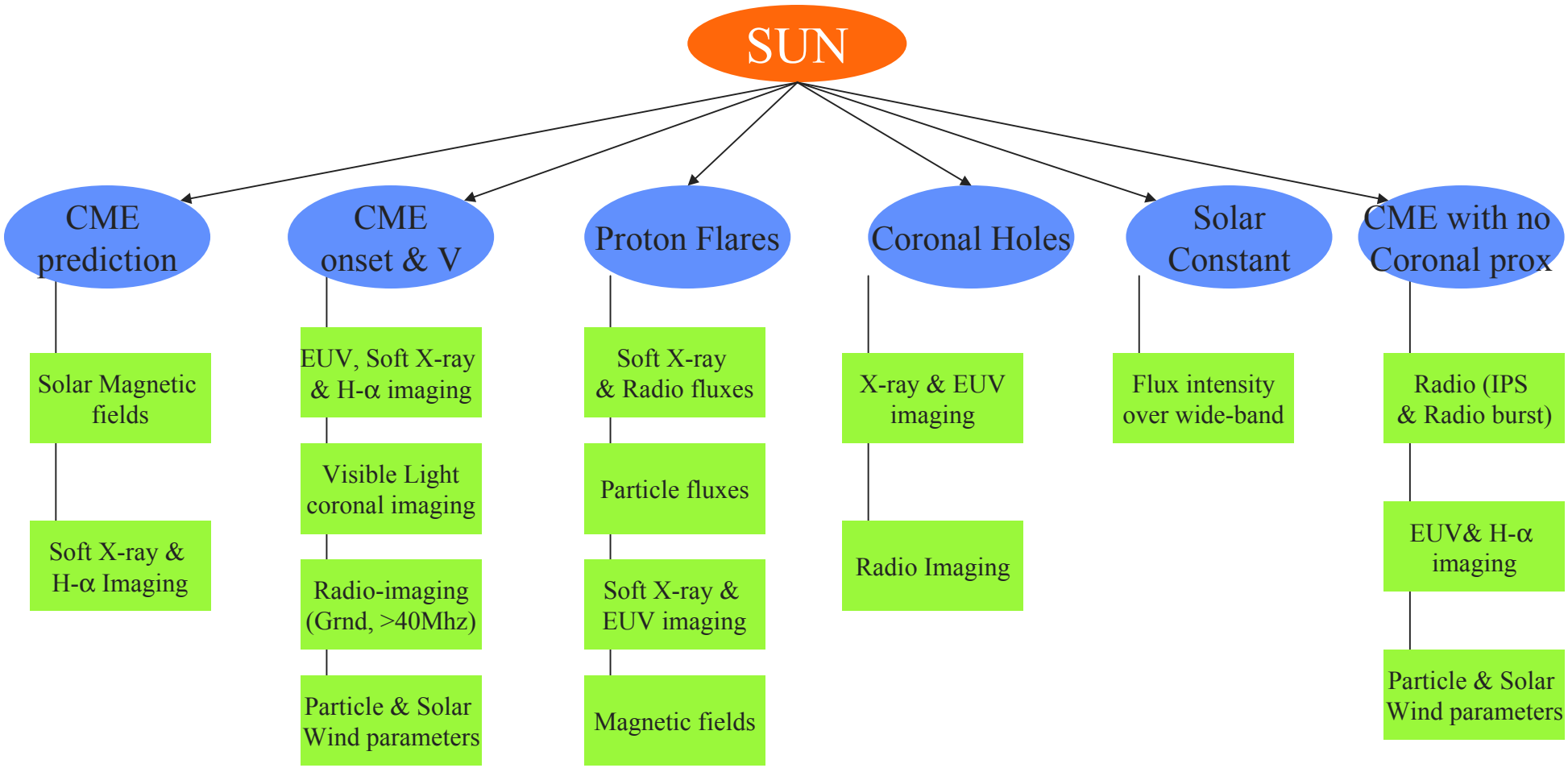
From User to Instrument

	Phenomenon	Observable	Users
Sun	CME (prediction)	Solar magnetic fields Soft X-ray and H-α ? imaging	Satellite operators
	CME (onset and velocity)	EUV, soft X-ray and H-α imaging Visible light coronal imaging Radio (MHz-GHz imaging, ground-based) Particle and solar-wind parameters	Satellite operators
	Proton Flares	Soft X-ray flux and radio fluxes Particle fluxes Soft X-ray and EUV images Magnetic fields	Satellite operators, launchers humans in space, research
	Coronal Holes	X-ray and EUV images, radio	Spacecraft operators
	Solar constant	Flux intensity over wide-band	Climate - Humans on Earth
	CME with no coronal proxies	Radio (IPS and radio bursts) Particle and solar-wind parameters Hα, EUV	Satellite operators

From User to Instrument



From User to Instrument



From User to Instrument

	Key parameters	Instruments
Solar	Solar magnetic field	3
	EUV/UV spectral flux	1,2,6,8
	CME lift-off time and velocity	1,2,4,5
	Solar energetic particle flux	9
	X-ray, Hα, EUV, UV imaging	1,2,5
	Radio signatures of shocks	7
Interplanetary	IMF topology	13
	Solar wind velocity	10 or 11
	Solar wind dynamic pressure	10 or 11
	Energetic particle flux	9
	Radio signatures of shocks	7
Magnetosphere	eV-keV particles	11
	keV-MeV particles	12
	Magnetic field	13
	Electromagnetic wave spectrum	15
	Boundaries	11,13,14,15
Thermosphere	Neutral gas density profile with altitude	20,21
	Neutral wind velocities	19
Ionosphere	Electron density	18,17,25,24
	Electric field	16
	Convection electric field	16
	Auroral precipitation	18,22,23

Comparison with Current Status & Evolution

Instrument	Comments
SXR Imager	No X-ray instruments on SOHO; Similar to design of GOES-SXI
EUV Imager	Similar design to SOHO-EIT; half spatial resolution, higher cadence, fewer channels
Coronagraph	Similar to SOHO-LASCO; comparable spatial and temporal resolutions
Magnetograph	Line-of-sight magnetograph: very similar to SOHO-MDI; higher cadence Vector magnetograph: never flown before, similar to one planned for the LWS SDO mission
H-Alpha Imager	Not flown previously

Instruments	Comments
X-ray and EUV imager	Require space-based platform, atmosphere absorbs these wavelengths.
Coronagraph	Some measurements possible from the ground, but atmospheric scattering limits radial distance from solar disk that can be observed.
Magnetograph and H-alpha imager	Could be made from the ground, but continuous, reliable coverage would require an extensive network of ground-based observatories. Better coverage from space.

SYSTEM SCENARIOS (2/3)

- Rationale of SYSTEM SCENARIOS _2
  - Provide different levels of User 's Needs fulfillment
  - Definition of 3 Operational Approaches
  - Identify Essential components
  - Space + Ground Complementarity : no straightforward selection
  - Several Options for Solar observations : L1, GEO, LEO

SYSTEM SCENARIOS (3/3)

- FULL Scale Scenario
  - Ideal Space Weather programme : optimized Space Segment / complementary Ground Segment
  - Exhaustive Answer to User 's Needs

- MEDIUM Scale Scenario
  - Reduced Cost Space Weather programme
  - Space Segment cuts / Enhanced Ground Segment
  - Largely Improved Monitoring : Sun & Solar Wind

* Minimize Space Segment Cost

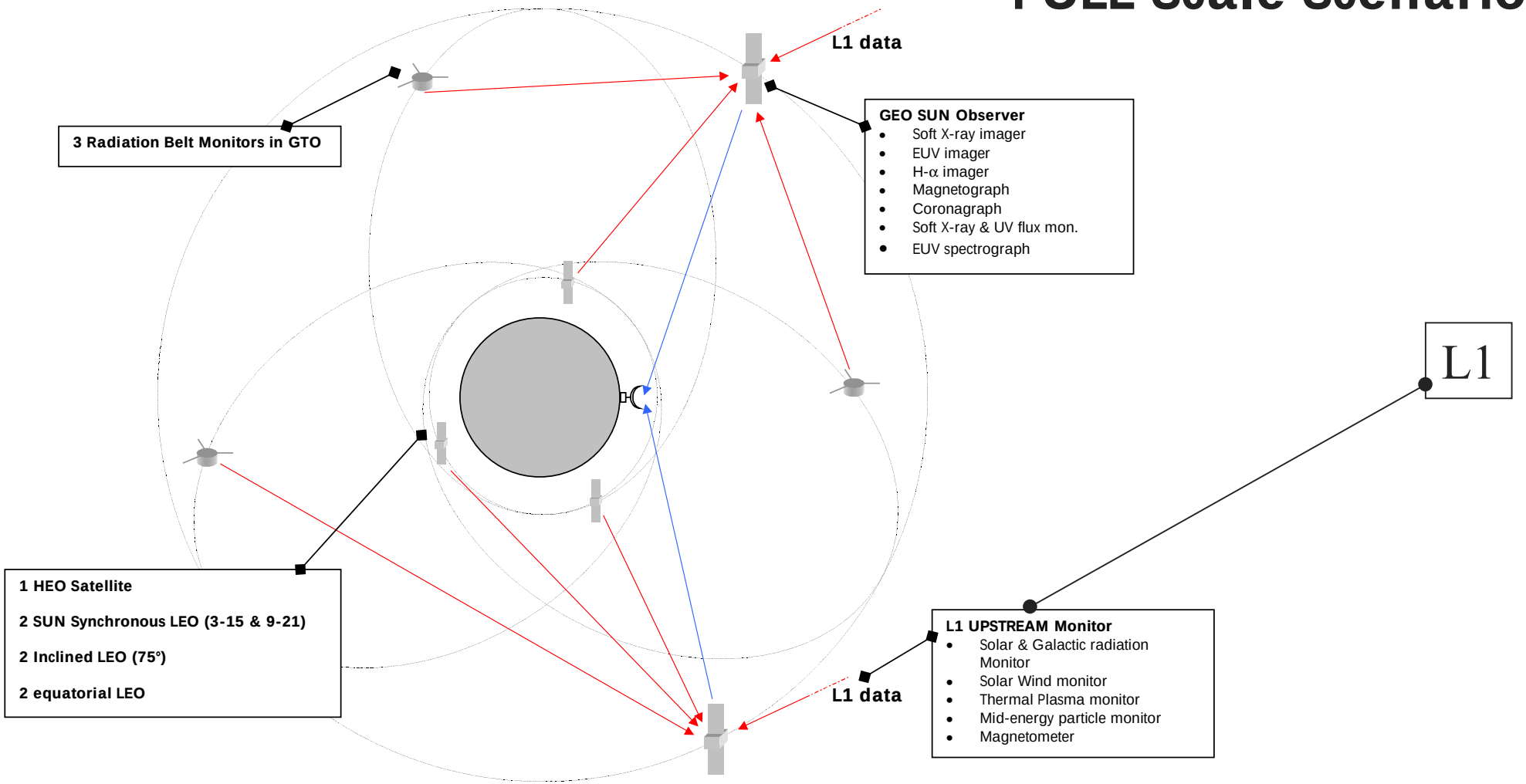
* Keep real-time as much as possible

- LOW Scale Scenario
  - Minimum Space Segment Cost Space Weather Prog
  - Essential Space Observations / Enhanced Ground Segment

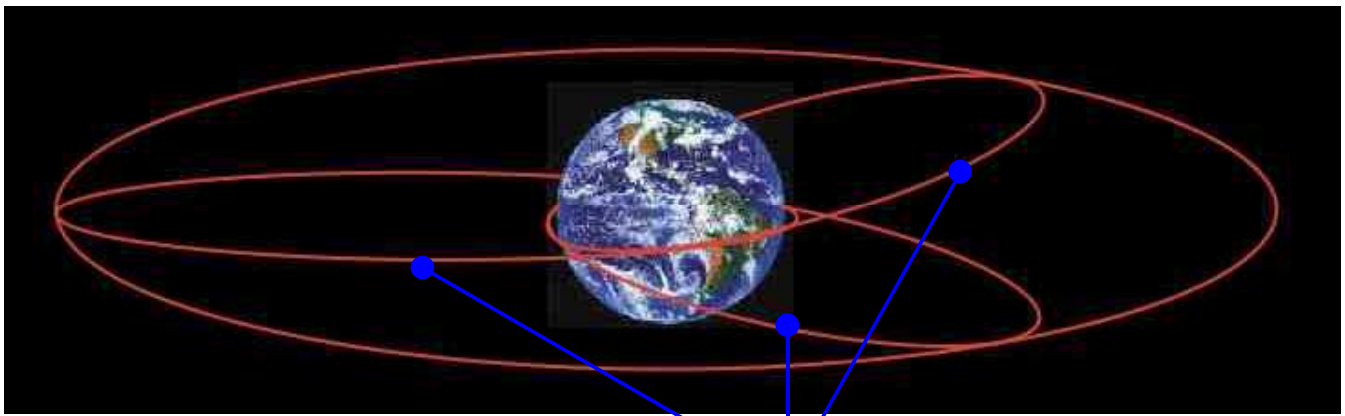
Operational Scenarios : Space Segment

	Full Scale	Medium Scale	Low Scale
Solar Observation	(1) 2 Geosynchronous Spacecrafts with full intrumentation (2) L1 Instruments on Upstream Monitor : radio-spectrograph (< 40 MHz min; up to 200 MHz if feasible)	(1) L1 Observer with low freq. Radio-spectrograph(< 40MHz) (2) H-α imager with reduced TM rate (3) Suppression of SXI	(1) LEO satellite, with limited instruments : • EUV Imager • Coronagraph • EUV Flux • EUV Spectrometer
Solar Wind-heliosphere	(1) Upstream Monitor at L1 with full Instruments and including radio-spectrograph	(1) Upstream Monitor at L1 combined with Solar observation (separated if less costly / more heritage)	1. Upstream Monitor at L1 with full Instruments
Magnetosphere Monitoring (Radiation Belts)	1. Three Equatorial spacecrafts in GTO 2. Hitch-hikers on GEO/MEO s/c	1. Three Equatorial spacecrafts in GTO 2. Hitch-hikers on GEO/MEO s/c	1. One Equatorial spacecraft in GTO 2. Hitch-hikers on GEO/MEO s/c
Ionosphere / Thermosphere	1. High Excentric Spacecraft 2. Two Sun-synchronous LEO 3-15 & 9-21 LT (600km) 3. Two inclined LEO (75°) on the same orbit 4. 1 pair of equatorial LEO on the same orbit	1. Two Sun-synchronous LEO at 600km 3-15 & 9-21 LT 2. Hitch-hikers for radiation belt	

FULL Scale Scenario



FULL Scale & MEDIUM Scale Scenarios
Magnetosphere Segment Radiation Belts Monitors



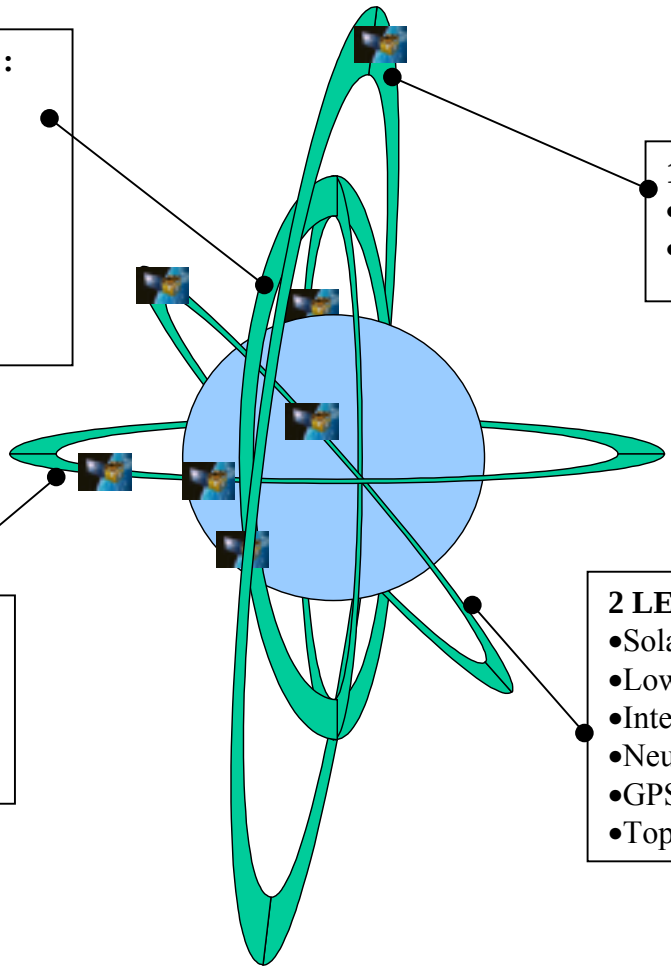
Radiation Belt Monitors on 3 GTO-type orbits

- Thermal Plasma monitor
- Mid-energy particle monitor
- Magnetometer
- Waves

FULL Scale Scenario : Ionosphere/Thermosphere Monitors

2 LEO Sun-synchronous 3-15 & 9-21 :
- Solar & Galactic radiation monitor
- Low energy plasma monitor
- E-field antennae
- Neutral mass spectrometer
- GPS receiver
- Topside sounder

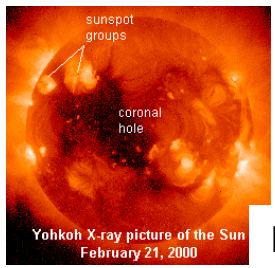
1 Highly Elliptical Orbit Satellite
- UV imager
- Visible imager



2 LEO equatorial :
- Interferometer
- Neutral mass spectrometer
- GPS receiver
- Topside sounder

2 LEO High Inclination :
- Solar & Galactic radiation monitor
- Low energy plasma monitor
- Interferometer
- Neutral mass spectrometer
- GPS receiver
- Topside sounder

LOW Scale Scenario



L1

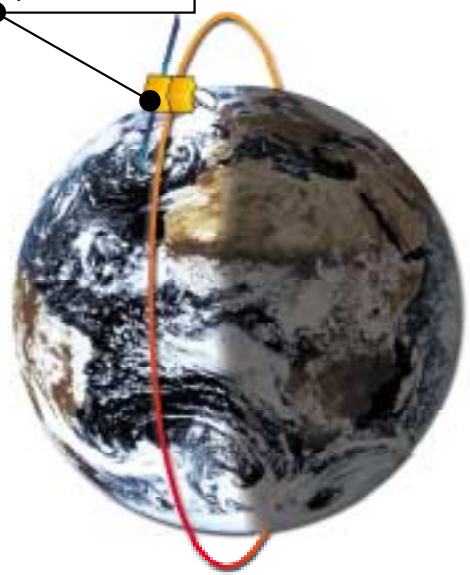
X

Upstream L1 Monitor :

- Galactic & cosmic rays detector
- Solar Wind monitor
- Thermal Plasma monitor
- Mid-energy particle monitor
- Magnetometer
- Low frequency radio-spectrograph (<40MHz)

SUN LEO Observer :

- EUV Imager
- EUV Flux Monitor
- EUV spectrometer
- Coronagraph



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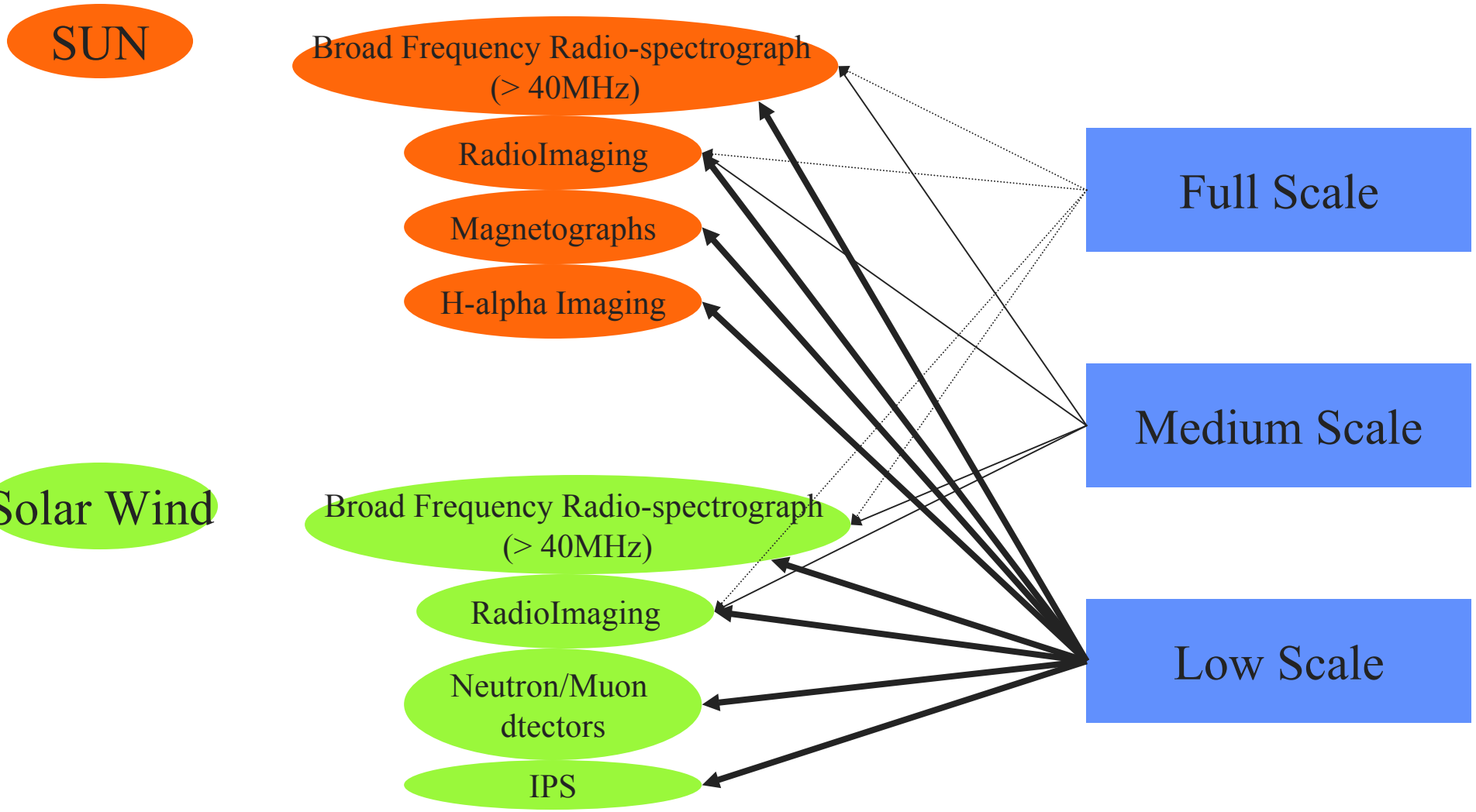
1 Radiation Belts Monitor

Operational Scenarios : Ground Segment

	Full Scale	Medium Scale	Low Scale
Solar observations	Broad frequency radio spectrographe (above 40 MHz) Radio imaging.	Broad frequency radio spectrographe (above 40 MHz) Radio imaging.	Broad frequency radio spectrographe (above 40 MHz) Radio imaging. Magnetograph network. Hα network.
Upstream (including interplanetary)	Broad frequency radio spectrograph. Radio imaging. Neutron and Muon detectors.	Broad frequency radio spectrograph. Radio imaging. Neutron and Muon detectors.	Broad frequency radio spectrograph. Radio imaging. Neutron and Muon detectors.
Magnetospheric monitoring	Covered under I/T monitoring	Covered under I/T monitoring	Covered under I/T monitoring
Ionosphere/thermosphere Monitoring	Magnetometer networks. Positioning networks SuperDARN network. F10.7cm	Magnetometer networks. Positioning networks SuperDARN network F10.7cm Ionosonde Network	Magnetometer networks. Positioning networks SuperDARN network F10.7cm Ionosonde Network

Operational Scenarios : Ground Segment



ESA Study for SPACE WEATHER PROGRAMME

Current Perspective (1/2)

- Hitch- Hikers :
  - Only particles detection/fluxes
  - Limited mapping / independance
  - piggy-back payloads on various satellites / various orbits :
    - All European GEO
    - GALILEO
    - MSG / METOP
    - LEO of National Agencies
    - All ESA close-to-earth Spacecrafts
- Current Scenario :
  - SOHO + ACE => end of life : 2005/2006
  - Ground far from operational

Current Perspective (1/2)

Current Situation

	Space	Ground
Solar Observation	(1) SOHO : ***lifetime 2006*** (2) SXI on GOES : ***USA*** (3) Solar-B in LEO : ***JAPAN/USA***	(1) Magnetographs (incomplete and not 24Hrs) (2) H-a network (incomplete and not 24 hrs) (3) Coronagraphs (not adapted) (4) Radio-spectro & Imaging (not complete)
Solar Wind-Heliosphere	(1) ACE : ***lifetime 2005***	n.a.
Magnetosphere Monitoring (RBM)	Very few Hitch-hikers : GOES & POES; GE-americom (USA); LANL's ones' (USA) ; COMRAD on Stentor in GEO (Fr); … -> data not accessible for many of them	(1) Magnetometer networks
Ionosphere / Thermosphere		(1) Ionospheric sounders (2) SUPERDARN network (incomplete) (3) Intermagnet network (4) GPS Networks (partial) (5) F 10.7 cm measurements

Main Outcomes (1/2)

- Space Segment
  - **Recommended Instruments :**
    - **H-alpha Imager**
    - **Radio-spectrograph (at least up to 40 MHZ)**
    - **Miniaturization of equipments**
  - **High level mapping of Magnetosphere/Ionosphere necessary to fill-up gaps in Storms tracking**
  - **Data Collection for Real-Time / Continuity is a Driving Feature of the System**
  - **Full Scale => GEO Sun Observation that serves as Data Retay Satellite for All other Spacecrafts**
  - **Optimisation of Space Segment**
    - **Orbits/Launch strategy is a driving parameter**
    - **All required platforms are within European capability**

Main Outcomes (2/2)

- Ground observatories & measurements

  - **Need to consolidate existing Sun Observation Network**
    - **Radio Imaging**
    - **Radio spectrographs**
    - **H-alpha telescopes**

  - **Need to re-inforce and ensure future operation of crucial ground networks like:**
    - **Superdarn radars**
    - **Magnetometers**
    - **GPS-based measurements**
    - **Ionosondes**

Space Segment Pilot Projects (1/4)

- Selection of Priority Mission
  - Combination of various criteria :
    - programmatic;
    - technical need ;
    - development cost ;
    - time-criticality (Sun cycle)
  - Priority to « Most essential segments » wrt continuity of a Space Weather prediction service
  - Complementarity with International Programmes / European Autonomy
  - 3 Projects selected independantly of the Scenarios

Space Segment Pilot Projects (2/4)

- Pilot Project 1 : **UPSTREAM L1 Monitor**
  - Instrumentation :
    - Solar & Galactic radiation Monitor
    - Solar Wind Monitor
    - Thermal Plasma monitor
    - Mid-energy particle monitor
    - Magnetometer
    - Low frequency Radio-spectrograph (< 40 MHz)
      - for Sun Monitoring, but necessary and best use in L1
  - Platform/Orbit : dedicated spinned satellite in L1
  - Rationale :
    - in-situ Solar Wind monitoring
    - service continuity => replace ACE

Space Segment Pilot Projects (3/4)

- Pilot Project 2 : **SUN LEO Observatory**
  - Instrumentation :
    - EUV Imager
    - Coronagraph
    - EUV Flux Monitor
    - EUV Spectrometer
  - Platform/Orbit : LEO Mini-satellite class
  - Rationale :
    - SUN monitoring critical (i.e. EUV)
    - service continuity => replace SOHO
    - low cost ,***quick operability***.
  - Suggested evolution : add H-alpha telescope if within satellite capacity

Space Segment Pilot Projects (4/4)

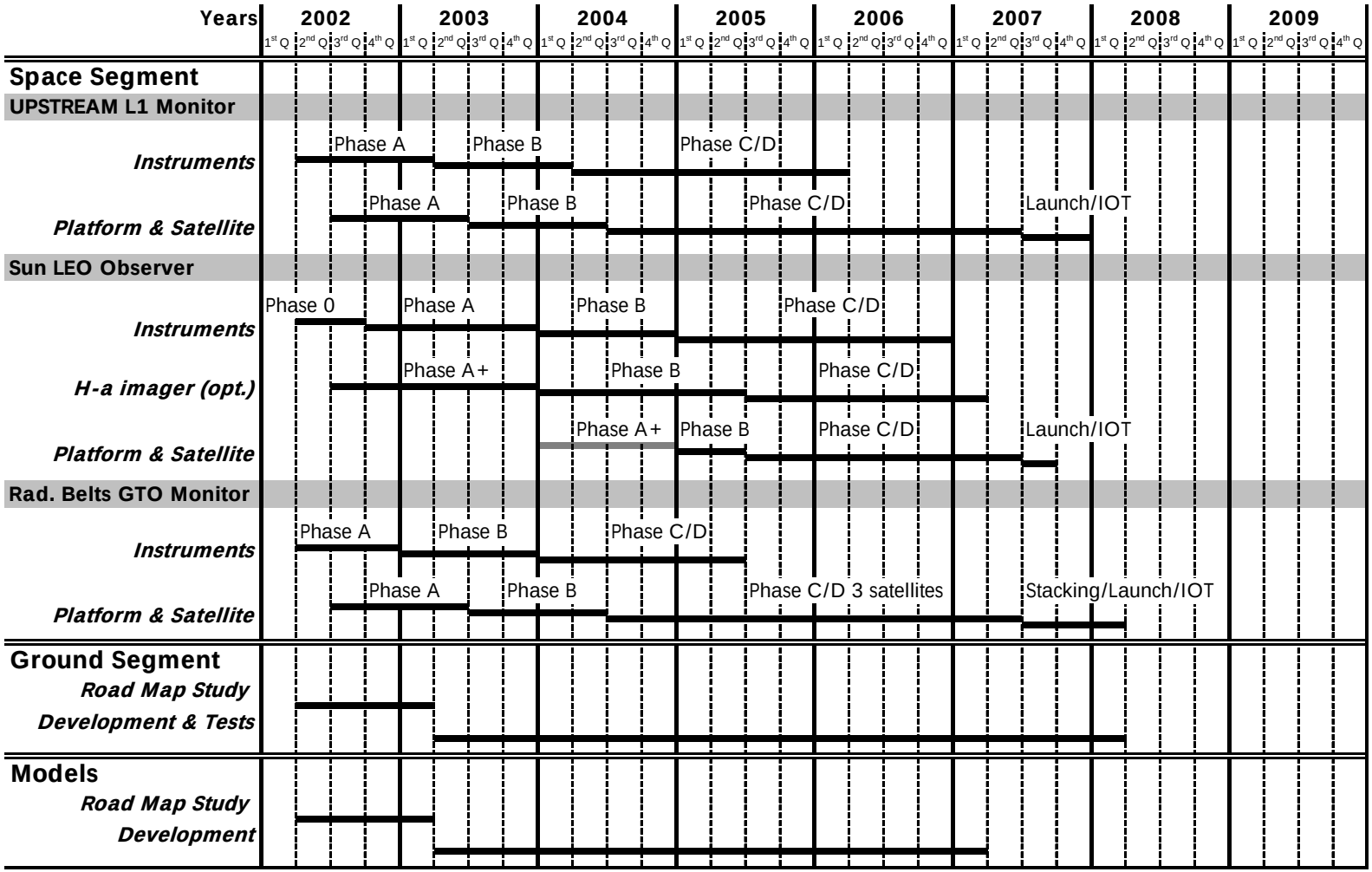
- Pilot Project 3 : **Radiation Belt GTO Monitors**
  - Instrumentation :
    - Thermal Plasma monitor
    - Mid-energy particle monitor
    - Magnetometer
    - Waves Instrument
  - Platform/Orbit : 3 Mini Satellites in 3 diff. GTO-type equatorial orbit
  - Rationale :
    - big gap in Space Weather monitoring
    - Direct application to Space Environment
    - Ideal Cooperation (3 Orbits)
  - Suggested evolution : add Solar & Galactic radiation Monitor for high energy particle + heavy Ions .

Programmatics

Programmatics : Space Segment (1/2)

- Initialise pre-design studies for Pilot Projects Instruments and Platforms to meet ACE and SOHO replacement
- Proposed Schedule :
  - Upstream L1 Monitor :
    - Instruments & Satellite Ph A: 2nd Q 2002
    - Instruments Phase B/C/D : 1st Q 2003
    - Platform/Sat Phase B/C/D: 2nd Q 2003
    - Launch Date : 3rd Q 2007
  - Radiation Belts GTO Monitors :
    - Instruments & Satellite Ph A: 2nd Q 2002
    - Instruments Phase B/C/D : 1st Q 2003
    - Platforms/Sat PhaseB/C/D: 3rd Q 2003
    - Launch Date : 3rd Q 2007
  - SUN LEO Monitor :
    - Instruments Phase 0 : 2nd Q 2002
    - Instruments & Satellite Ph A: 4th Q 2002
    - Instruments Phase B/C/D : 1st Q 2004
    - Platform/Sat Phase B/C/D: 2nd Q 2005
    - Launch Date : 3rd Q 2007

Programmatics : Space Segment (2/2)



ESA Study for SPACE WEATHER PROGRAMME

Programmatics : Ground Segment

- Ground Segment : Assess, within early 2002
  - Upgrade of existing facilities
  - Calibration requirements
  - New developments : additional sites; new technologies
  - Adaptation to operational use => raod map
  - Data networks development
- PARTNERSHIPS TO BE SETTLED

CONCLUSIONS

CONCLUSIONS

- Different options exists to initiate a Space Weather programme
- Monitoring Space Weather segments => specific Requirements
- Essential measurements are required in Space for Service continuity
- Ground observation & measurements compulsory BUT => need developments/upgrading
  - Leading Entity ?