FINAL REVIEW

ALCATEL/LPCE Team Presentation

ESTEC-Noordwijk, December 6th, 2001

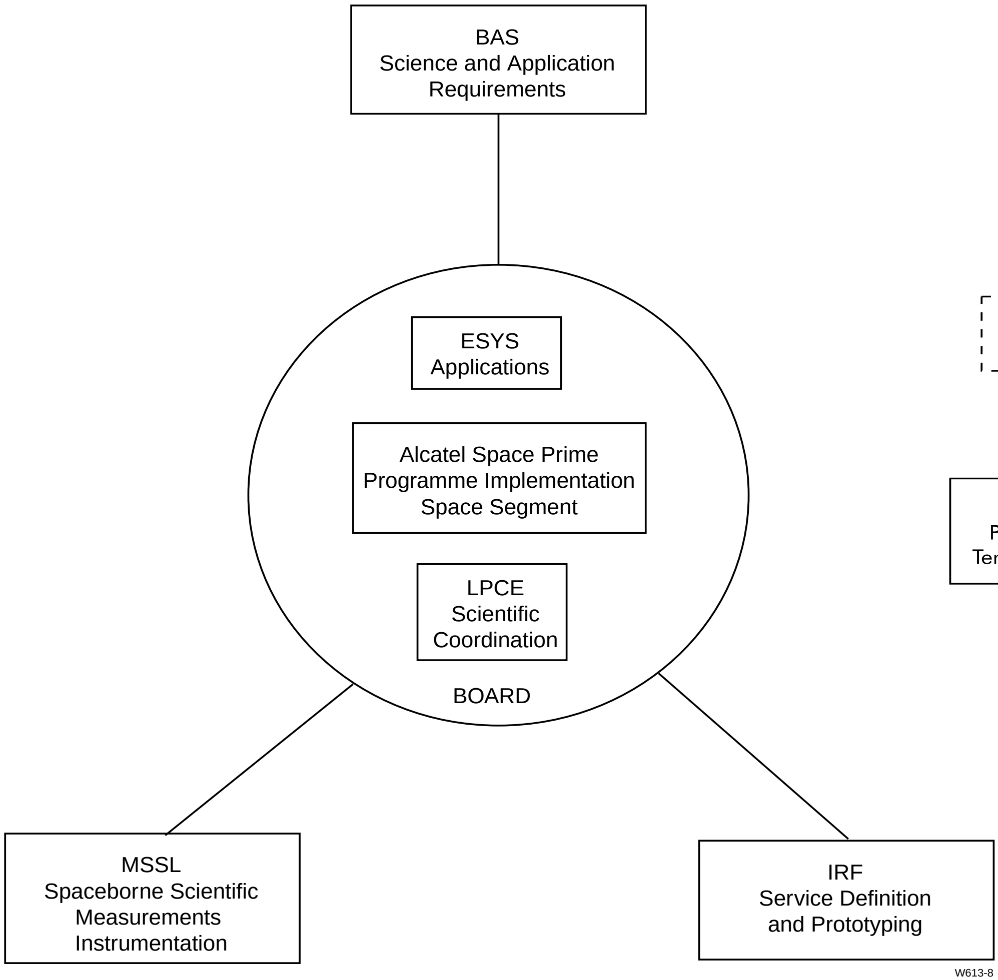
CONSORTIUM Members

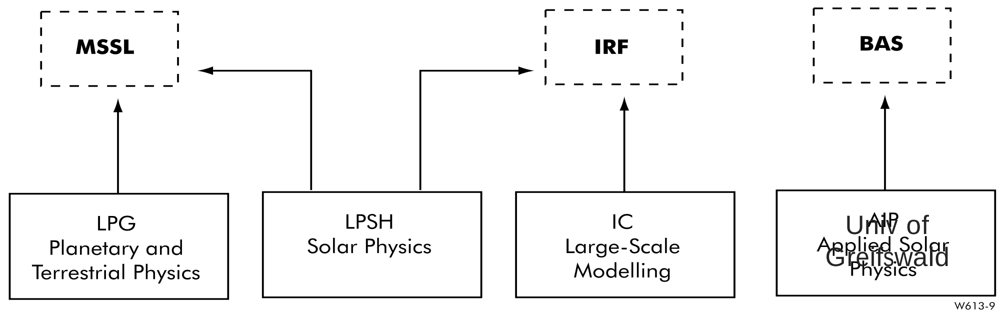
- Team Members (1/2)
  - ALCATEL Space (Fr) : Prime contractor, Space Segment
  - LPCE (Orléans-Fr) : Scientific Prime contractor
  - IRF-Lund (Suède) : Services & Prototyping
  - British Antartic Survey (UK) : User ’s assessment .
  - MSSL (UK) : Space Instrumentation and System requirements
  - ESYS (UK) : Market Analysis

CONSORTIUM Members

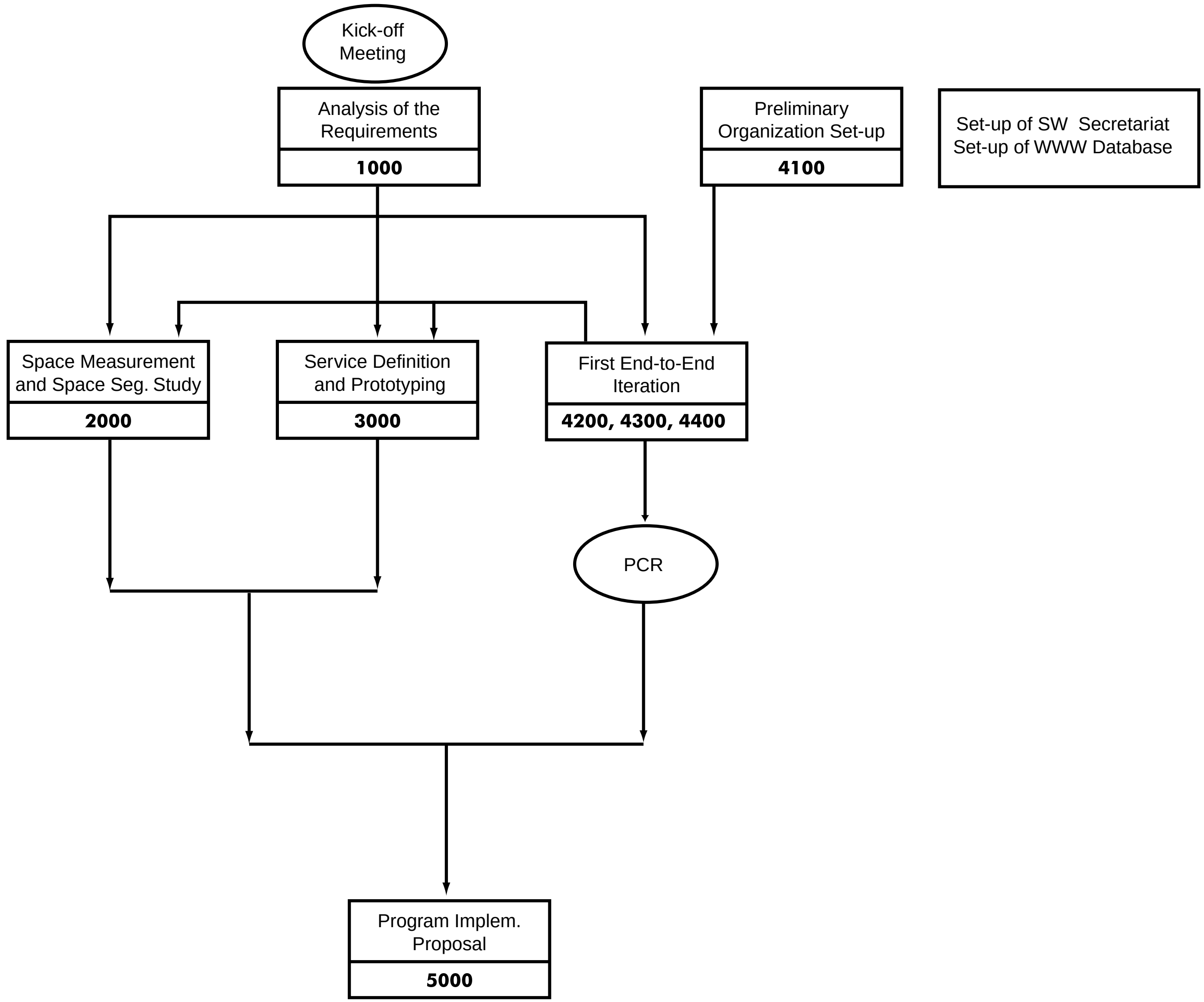
- Team Members (2/2) :
  - LPG (Grenoble-Fr) : Parameters and models
  - LPSH/ Obs de Paris(Meudon-Fr) : Ground Segment & Sun Observation
  - Imperial College (UK) : Prototyping and Modelling
  - Université Greifswald (D) : SW Parameters

TEAM Organisation





STUDY FLOW


Kick-off Meeting
Analysis of the Requirements
1000
Preliminary Organization Set-up
4100
Set-up of SW Secretariat
Set-up of WWW Database
Space Measurement and Space Seg. Study
2000
Service Definition and Prototyping
3000
First End-to-End Iteration
4200, 4300, 4400
PCR
Program Implem. Proposal
5000

STUDY DRIVERS

- Overview of Current knowledge & understanding
  - Science
  - Space Weather Parameters
  - User 's Interest
- Flexibility and Options
  - Space instruments
  - Ground Instruments
  - Ground Data Handling
- European Autonomy / Use of European Assets
- Operational System

STUDY MAIN ACHIEVEMENTS (1/2)

- Investigation of User 's Needs and Market :
  - Classification
  - Characterization
  - Quantification
  - Parametrization

- Reference / Synthetic Tables
  - Space Weather Parameters
  - Instruments for each Parameter (Space + Ground)
  - Models Overview
  - Space Weather Forecast Capabilities

STUDY MAIN ACHIEVEMENTS (2/2)

- Prototypes of services
  - AI Based predictions
  - Physical-models based predictions
- Multiple System Scenarios
  - Different levels of fulfillment of the requirements
  - Different levels of fundings
- Action plan for a European Programme
  - Guidelines for Structures
  - Priorities
  - Key Elements

System Scenarios
and
Pilot Projects

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

SYSTEM SCENARIOS (2/3)

Rationale of SYSTEM SCENARIOS _2

- ESA SOW requirements :

- Approach 1 / Full Scale : shall contain a full scale space segment including new development and new platforms
- Approach 2 / Medium Scale : shall be based on the equipment of all european spacecraft with hitchhiker standard plasma/field/radiation environment monitors
- Approach 3 / Low Scale : shall focus on the use of existing assets without any supplementary hardware compared to the existing or anticipated space programmes of ESA member states

- Redefinition of 3 Operational Approaches
  - Approach 1 very expensive / ambitious ; does not offer flexibility wrt fundings
  - Approaches 2 & 3 ----> No Operational Service
- Need to identify Essential components
- Several Options for Solar observations
  - Lagrange 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

LOW Scale Scenario

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

HITCH-HIKERS Scenarios :

- Space component = only piggy-back payloads
- Ground Segment as per Low Scale

Passive Scenario :

- Space Segment as per today
- No investments

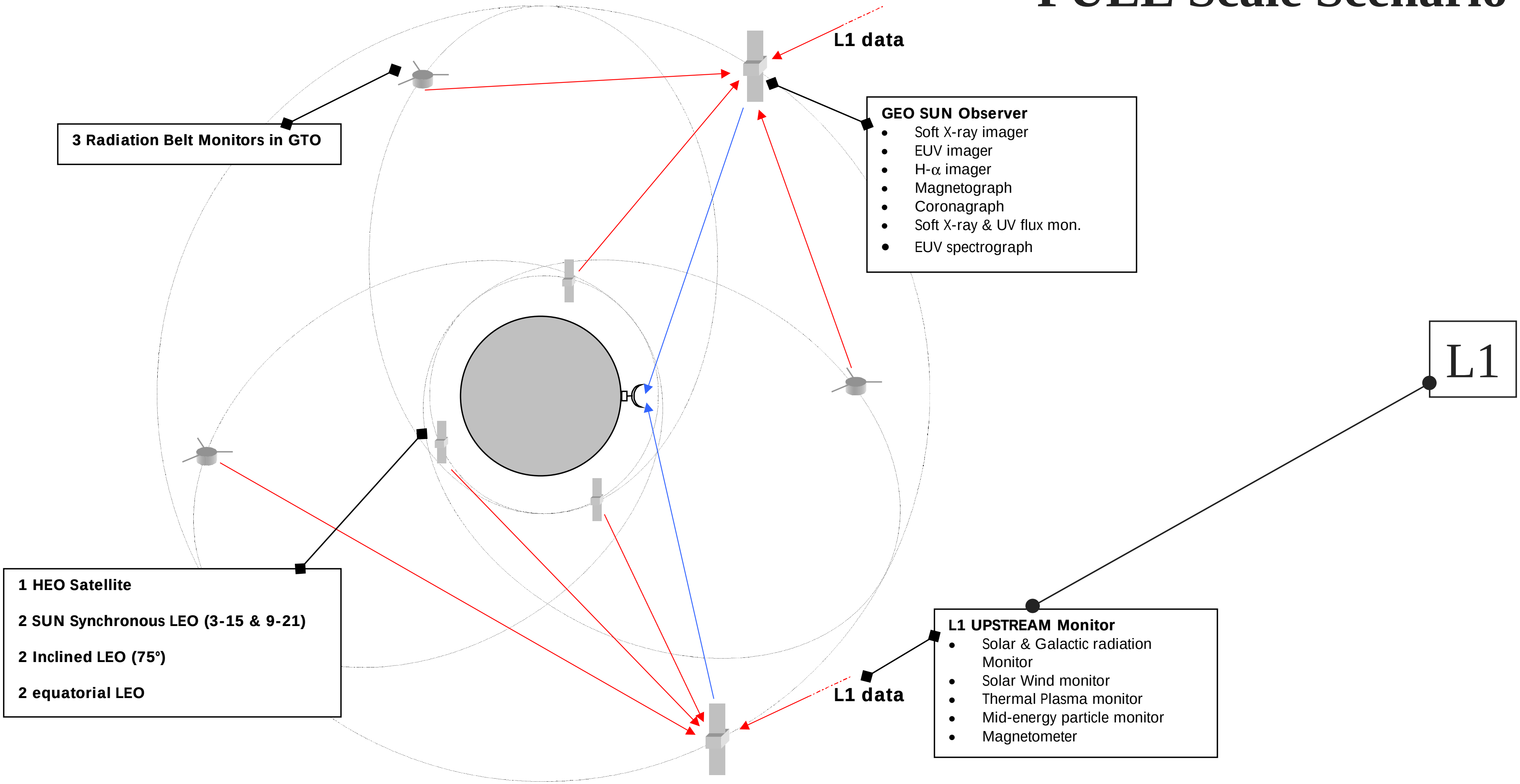
Operational Scenarios : Space Segment

	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	

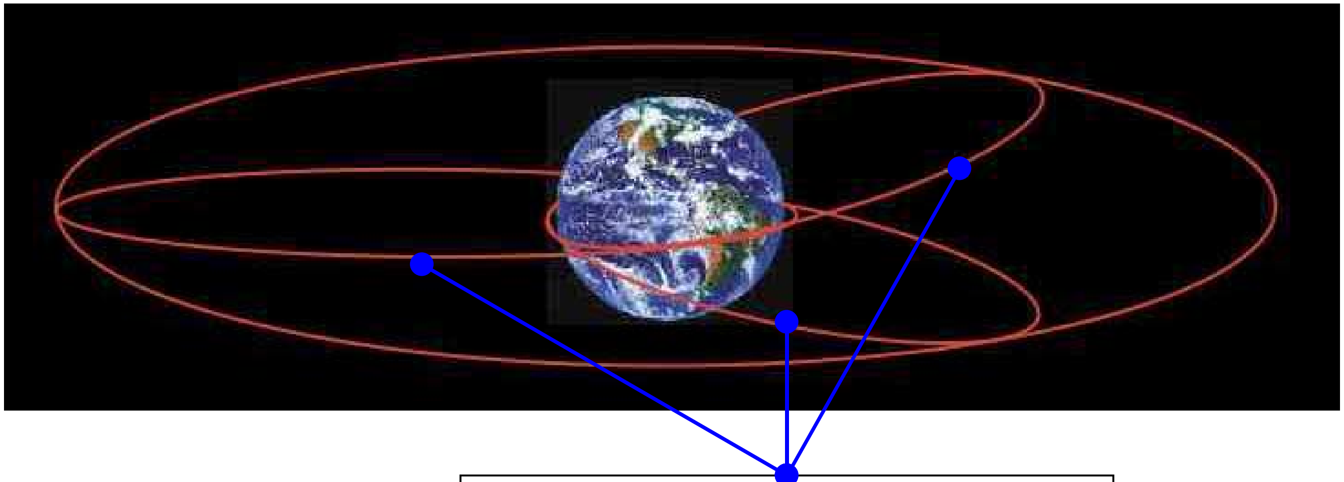
Operational Scenarios : Ground Segment

	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

FULL Scale Scenario



FULL Scale & MEDIUM Scale Scenarios
Magnetosphere Segment Radiation Belts Monitors

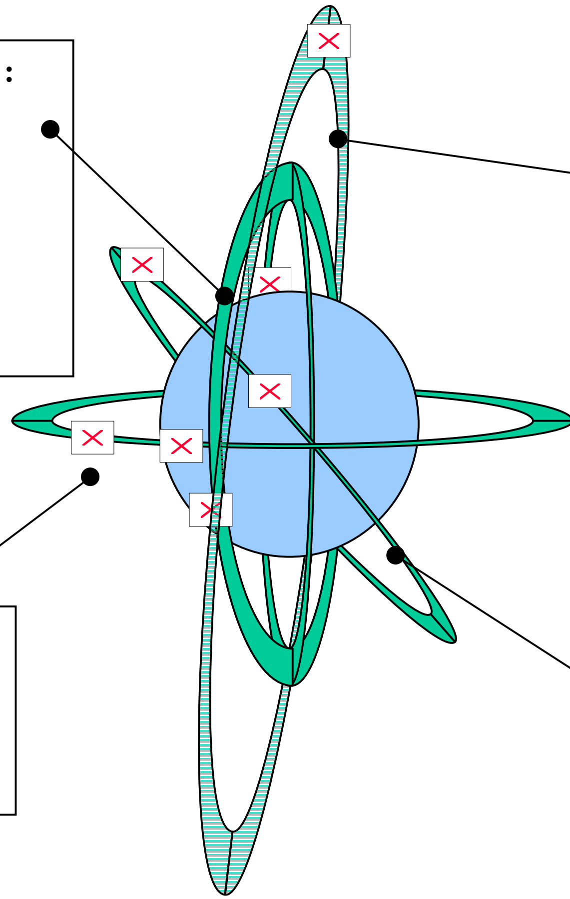


Radiation Belt Monitors on 3 GTO-type orbits
- Thermal Plasma monitor
- Mid-energy particle monitor
- Magnetometer
- Waves

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

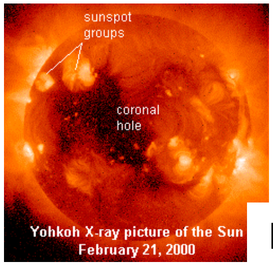
1 Highly Elliptical Orbit Satellite
- UV imager
- Visible imager



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

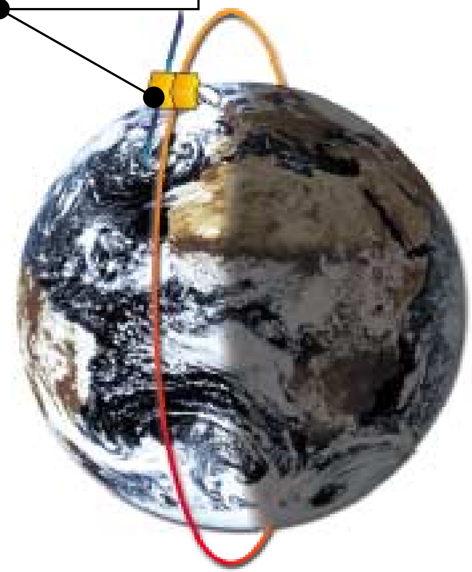
LOW Scale Scenario



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



+
1 Radiation Belts Monitor

Non Operational Scenarios (1/2)

- Hitch- Hikers Scenario :
  - piggy-back payloads on various satellites / various orbits :
    - All European GEO
    - GALILEO
    - MSG / METOP
    - LEO of National Agencies
    - All ESA close-to-earth Spacecrafts
  - Ground as per Low Scale

- PASSIVE Scenario :
  - SOHO + ACE => end of life : 2005/2006
  - Ground as per Low Scale

Non Operational Scenarios (2/2)

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)**
    - **All required Instruments are within european capability**
  - **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**

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 :
    - Shall not be directly correlated with the future European Scenario
    - Shall be used to consolidate Feasibility/Accessibility of some segments

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 :
    - criticality of the Solar Wind monitoring : specific & unique location
    - service continuity => urgent need of back-up to ACE
    - autonomy for Europe

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 :
  - criticality of the SUN monitoring : specific / strategic
  - service continuity => urgent need of back-up to SOHO
  - autonomy for Europe
  - low cost , small development schedule ==> ***quick operability***
  - similarity with SOLAR-B => cooperation/correlation ?
  - data collection to be optimised/developped if quasi real-time required.
- 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 SW monitoring currently
    - autonomy for Europe
    - Low cost can be reached with ARIANE launch
    - Direct application to Satellite Operators => strong user's interest
  - Suggested evolution : add Solar & Galactic radiation Monitor for high energy particle + heavy Ions .

Programmatics
and
Costs

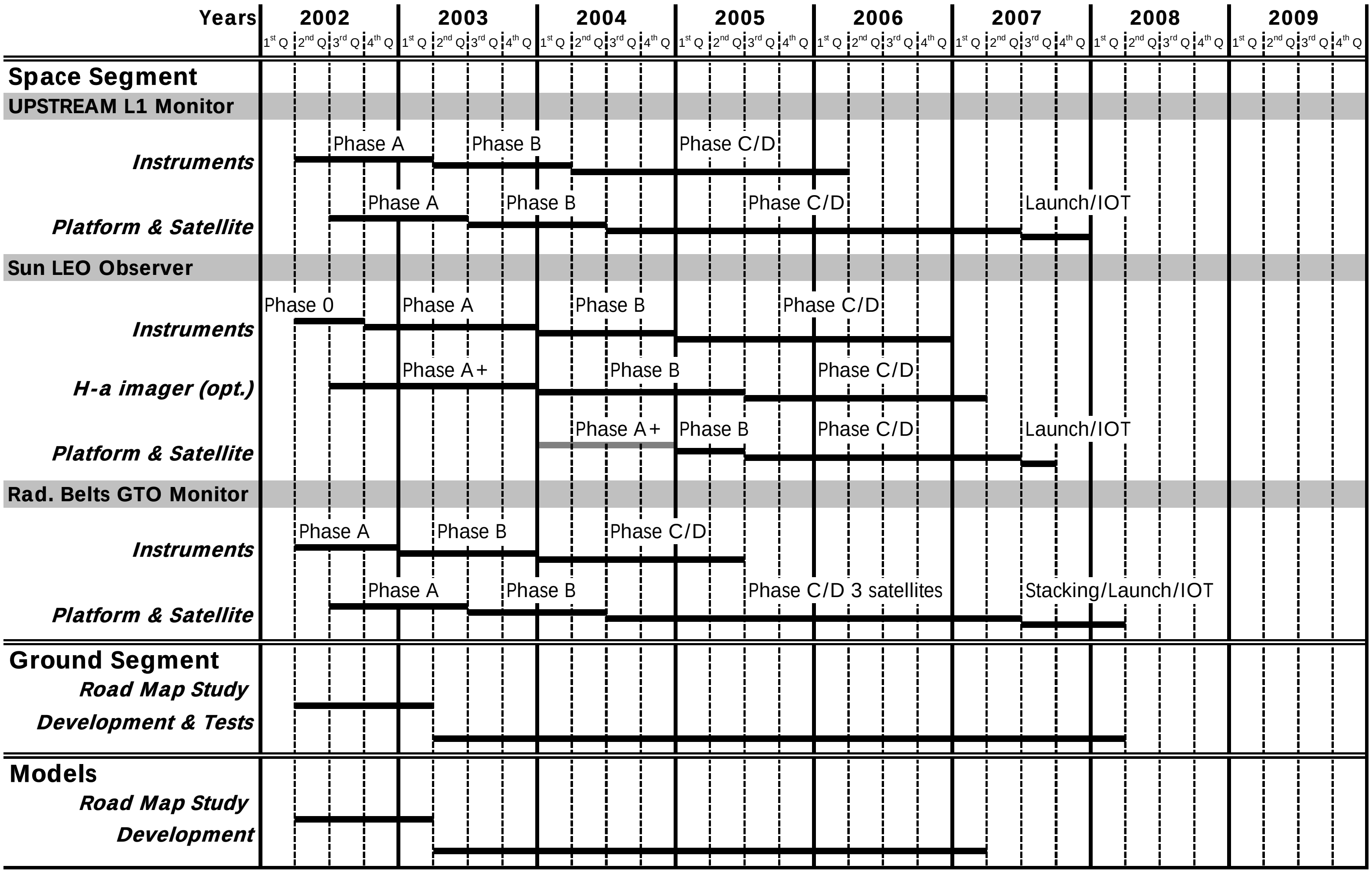
Programmatics : User 's Community

- FEDERATE User 's Community
  - Consolidate the Requirements : qualitatively + quantitatively
  - Avoid unique NOAA/SEC Boulder reference
- Study / Demonstration , in 2002, of WORST CASES for each leading Application like :
  - Satellite Operation / Orbit Control
  - Power Grids
  - Man in Space

Programmatics : Space Segment

- 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/satellite Phase B/C/D: 2nd 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/satellite Phase B/C/D: 2nd Q 2005
    - Launch Date : 3rd Q 2007
  - Radiation Belts GTO Monitor :
    - Instruments & Satellite Ph A: 2nd Q 2002
    - Instruments Phase B/C/D : 1st Q 2003
    - Platforms/satellites PhaseB/C/D: 3rd Q 2003
    - Launch Date : 3rd Q 2007

Programmatics : Space Segment



Programmatics : Ground Segment

- Ground Segment : Study in early 2002 for addressing in details
  - 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

Programmatics : Models /Services

- Models : dedicated review starting in 2002
  - Use Study Outcomes for Detailed objectives of developments
  - Priorities : short term / mid-term
- Services :
  - Urgent need to a Follow-on of Prototyping Activity to demonstrate applications
  - Identify a Federating Entity : Reference / Coordination of Products development

Programmatics : Models Priorities 1/2

Location	Models	Based on	Input	Output	P/E	State of Develop^{nt}	Observations Needed for implement^{on} and development	Remarks	Recom^{ed}Prior of model^{ng} devel^{nt} (FTEs)
Sun + Interplanetary	CMEs	Satellite ground	Speed Start Direct Side N/S **B** at Sun	Speed. Field. Helicity. Proton flux. Arrival time at 1 AU.	P+E	Extensive	Coronagraph EUV, H_{α}. +Stereo coronagraph +Photospheric field Solar wind radio. Cosmic ray muons	Crudely available now. Medium – long term for better models. Physics mediocre.	Medium
Sun + Interplanetary	Recurrent streams	Satellite + ground	**B** at Sun	Speed at 1 AU. Kp, Ap	P+E	Operational	Solar fields. Coronal hole bdy	Fast prototype at SEC (Wang + Sheeley)	Use existing
Sun	Sunspot number	Ground	sunspots	Solar cycle	E	Operational	Sunspot number	Physics not understood.	Low
Sun	Solar activity + interior	Satellite, ground	**B** at Sun. **V** at Sun	Medium term activity	P+E	Research	Photospheric fields and motions	Physics based helioseismolog y	Medium/High
Sun	EUV irradiance	Satellite, ground	EUV + F10.7	EUV flux	E	Operational	EUV + radio spectra	Need cnts calibrated data	Medium
Sun	Flares/CME start	Satellite, ground	**B** at Sun, topology	Eruption time. Class of flare. Particle signature	P+E	"operationa l"	Photospheric field. Coronal structure + emission	Difficult!	Low

Programmatics : Models Priorities 2/2

Location	Models	Based on	Input	Output	P/E	State of Develop^{nt}	Observations Needed for implement^{on} and development	Remarks	Recom^{ed}Prior of model^{ng} devel^{nt} (FTEs)
Magnetosphere + ionosphere + ground	Indices + tech. systems	Sat at L1, Mag Ntwk	Solar wind	Kp, Dst, AE. GICs.	P+E	Extensive / operational	**B** and **V** in solar wind	Needs development.	Medium
Geospace	Satellite anomalies	Satellite at L1	Solar wind	Risk	E	Operational	**B** and v in solar wind	Needs major development	Medium
Magnetosphere	Radiation environment	Satellite at L1	Solar wind	Flux at GEO (MeV)	P+E	Research	**B** and v in solar wind	Needs work. (Baker/Li)	Use existing
Magnetosphere	Radiation Environment	GEO satellite	Flux at GEO (seed). Indices. SW Neutrals. Waves	Flux at GEO + inner belt	P+E	Research	Particle + wave (VLF: space ULF: ground) data. Indices. SW **B** and v. Field models. Rad measure.	Needs major development	High
Magnetosphere	Global	Physics	Solar wind. F10.7 etc.	**B, V** everywhere. Global currents	P	Research	L1	Needs major development	High
Ionosphere	Electrodynamics	Satellite + ground	Indices IMF Velocities	Convection Conductivities Precipitation	P+E	Pre-Operational	**E** IMF Solar irradiance	Realtime Continuous	Low
Ionosphere	State	Satellite + ground	Indices Nn Precipitation (magn. coupling)	Ne (+ Ni,Te,Ti, Vi)	P+E	Pre-Operational	Ne (topside+in situ) Solar irradiance		Medium
Thermosphere	State (1D and 3D) and dynamics	Satellite + ground	Indices Convection	Nn, Tn, Vn	P+E	Operational		Mostly valid at mid and low latitudes	High

COSTS

Operational Scenarios : elements of costs for Space

- *No costs on Grnd data processing/services*

- Full Scale
  - Spacecraft (incl Launch) 1100 Meuros
  - Grnd Data TM/TC Stations 34 Meuros
  - Opérations 2,5 Meuros/year
- Medium Scale
  - Spacecrafts (incl Launch) 580 Meuros
  - Ground Data TM/TC Stations 26 Meuros (for L1 only)
  - Opérations 2 Meuros / year (for L1 only)
- Low Scale
  - Spacecrafts (incl Launch) 255 Meuros
  - 1 TM/TC Station LEO (h/w) 4 Meuros

CONCLUSIONS

Main Outcomes from ESA Space Weather Study

- User 's Classification / Requirements Assessment & Parametrization
  - Essential TOOL for User 's Education
- Assessment of several Global System Scenarios to meet User 's Needs
- OPERATIONAL SPACE WEATHER Service is Within Reach
- PRIORITIES Given in the Perspective of an Operational Use
  - Space Segment
  - Ground Segment
  - Models development

Main Issues for a European Space Weather Programme

- Follow-on of Activities to Consolidate the Conclusions
- Find a European Leadership Entity
  - To Interface NOAA/SEC Boulder
- Find Political Support
  - ➯ **Provide Demonstration/Reference Cases of Space Weather Impacts/Risks**
- Prioritorize Projects for ensuring the continuation of current initiatives in development of Space Weather Prediction Services
  - Models
  - Space & Ground Measurements

Events	Forecasting the event	Forecasting the time of the event	Quantify the event's importance
Events at SUN			
No event	Y(U)	Y(D)	-
Coronal mass ejections (Halos)	Y(D)	N(D)	N(D)
Proton events	Y(D)	N(D)	Y(U)
Coronal holes	Y(U)	Y(U)	Y(D)
Solar activity/flares/X-ray, EUV radiation	Y(U)	N(D)	N(D)
Interplanetary events at L1			
Interplanetary CMEs and shocks	Y(D)(S)	Y(D)(S)	N(D)(S)
High speed plasma streams	Y(U)(S)	Y(U)(S)	Y(D)(S)
Earth's atmosphere			
Outer radiation belt electrons	Y(M)(L1)	Y(M)(L1)	Y(M)(L1)
Inner belt electrons and protons	Y(M)(L1)	Y(M)(L1)	Y(M)(L1)
Geomagnetic storms and substorms	Y(U)(L1)	Y(U)(L1)	Y(U)(L1)
Aurora	Y(D)(L1)	Y(D)(L1)	Y(D)(L1)
Ionospheric disturbance	Y(U)	Y(D)	Y(D)
Ionospheric scintillation	Y(U)	Y(U)	Y(U)
Thermospheric density increase	Y(U)	Y(U)	Y(U)

Effects on technological systems	Identification	Forecast-ing the event	Forecasting the time of the event	Quantify the event's importance
Satellite anomalies	N(D)	Y(D)	Y(D)	N(D)
Increased drag on satellite	Y	Y(U)	Y(D)	Y(D)
Communication distrurbannce	Y	Y(U)	Y(U)	Y(U)
Geomagnetically induced currents	Y	Y(U)	Y(U)	Y(U)

Legend

- Y= Yes, N=No, M=Mature, U=Useful, D=In Development
- Identification means whether or not we have identified the source of the space weather effect
- S=means that the forecast is basedon solar data.

L1=means that the forecast is based on data measured at L1.