Cosmic Vision 2015-2025
Technology Plan

Industry day, Estec 21 November 2008
Agenda

1- Status of Cosmic Vision Plan 10:00 - 10:40
   General Status - F.Safa

2- Overview of M-Class missions 10:40 – 11:30
   Solar Orbiter – Ph.Kletzkine
   Cross-Scale, Marco-Polo – P.Falkner
   Plato, Euclid – N. Rando

3- Overview of L-Class missions 11:30 – 12:10
   IXO mission – N.Rando
   LISA – A.Gianolio
   Outer Planet Mission – P.Falkner

4- Technology Development Plan Implementation 12:10 – 12:30
   Implementation procedures – M.Bavdaz
   Implementation schedule – M.Bavdaz
General Status
Mission Assessment Phase

First slice of Cosmic Vision Plan: Six M-Class and three L-Class missions are being assessed.

- **Mission selection**
  - Assessment Phase: ≥ 2 years
  - Down-selection & Payload AO: ≥ 2 years
  - Implementation Phase: ~ 5-6 years

- **Launch**

- **Spacecraft And Payload activities**
  - Assessment studies: n missions
  - Design consolidation & pre-developments: two missions
  - Development: one mission

- **ESA / Member States agreements**
  - Assessment Phase: LOE
  - Definition Phase: MLA

- **More on cosmic vision**: [http://sci.esa.int/science-e/www/area/index.cfm?fareaid=100](http://sci.esa.int/science-e/www/area/index.cfm?fareaid=100)
M class missions

- **Six missions studied**
  - Five from CV 2015-2025 first Call: Euclid, Plato, SPICA, Marco-Polo & Cross-Scale
  - Solar Orbiter now included in CV slice 1

- **Current progress is compatible with a M-mission down-selection end 2009/early 2010 and a launch in 2017/2018**
  - Phase 0 completed for all M missions. All industrial studies completed in Sept 09,
  - Technology Plan (TDP) in place for ESA and in progress for Member States on instrumentation
  - Technical readiness status vs 2017-2018 launch: should be achievable, based on Phase 0 ESA studies

- **Budget compatibility: The overall CV budget envelope (~ 900 ME) can reasonably accommodate two (or more) M missions**
  - Will be further consolidated by the end of the Assessment Phase, following consolidation of Member State contribution on the Payload
M missions: Short term schedule

• Industrial studies
  ✓ Funded by ESA General Study Programme (GSP)
  ✓ All studies are organised in three phases
    • Design trade-offs & baseline selection (Phase 1)
    • Detailed design (Phase 2)
    • Programmatic (Phase 3, 1 month)
  ✓ Mid-term (baseline selection): Dec 08-Jan 09
  ✓ Study completion: Sept 2009

• National Payload Studies
  ✓ Instrument national studies are made in parallel with industrial studies
  ✓ Interface with the Study Science Team, Industry and Instrument teams ensured by ESA
L class missions

• Three L-missions are being studied: Outer Planet mission (Laplace or Tandem), IXO and LISA
  ✓ Phase 0 completed for all L missions,
  ✓ Technology Plan (TDP) in place for ESA and in progress for Member States on instrumentation
  ✓ Slower progress than for M missions, due to international context, technical complexity and “primary” between Laplace/Tandem: Industrial studies not yet started, call for Instrumentation studies not yet issued.

• Technical readiness status vs 2018 launch: Not demonstrated
  ✓ Poor for Outer Planet missions and IXO, based on Phase 0 ESA studies and TDP elaboration.
  ✓ Subject to LISA Pathfinder success in-orbit and to satisfactory technology development progress for LISA.

• Budget compatibility: None of the missions can be afforded within the overall CV budget envelope, without international collaboration.
L missions: International collaboration scheme and constraints

• The three L missions are today foreseen in collaboration with the United States, and in addition for some with Japan
  ✓ Was the case for LISA: ESA/NASA mission
  ✓ Was the case for Outer Planet Missions
  ✓ Recent evolution for XEUS, re-named IXO (International X-ray Observatory)
  ✓ But NASA budget constraints are not compatible with L-mission launch before 2020

• Target launch date for L1 mission is now 2020
  ✓ Realistic schedule vs budget and technology preparation
  ✓ The Outer Planet down-selection (Jupiter or Saturn) is confirmed for beginning 2009 and will be jointly done by ESA/NASA
L missions: Short term schedule

- IXO Phase 0 (ESA study): Oct-Nov 08

- Laplace/Tandem down-selection: Jan 09

- IXO and Outer Planet studies (all dates preliminary)
  - Invitation to Tender: April-May 2009
  - Industrial Studies: July 2009-Dec 2010
  - Call for Instrument studies: Feb-March 09

- L1 mission down-selection: beginning 2011 (tbc)
Cosmic Vision timeline summary

L-class missions

- Laplace
- Tandem
- Lisa
- IXO

M-class missions

- Euclid
- Plato
- Spica
- Marco-Polo
- Cross-Scale
- Solar Orbiter

Launches:
- L1 launch (2012)
- M1 launch (2017)
- M2 launch (2018)
Overview of M-class missions
Current Industrial Work

- Preliminary Definition Phase B1 initiated in March 2008.
- Astrium Ltd, with Astrium GmbH and Alenia.
- Design Definition of Spacecraft, Heat Shield, Instrument Accommodation, Definition of Technology Development Activities.
- Programmatics, BepiColombo equipment re-use, Equipment Requests for Information, Schedule, Costing.
- System Requirements Review scheduled in Fall 2009.
Spacecraft Baseline
Spacecraft Critical Items

• SOLAR GENERATOR
  ✓ Hot case sized by temperature and solar flux
  ✓ Cold case sized by far-sun power demand
  => New, dual-side design needed
  Heritage from BepiColombo? (Array / PVA / Cell / diodes etc)

• HIGH GAIN ANTENNA
  ✓ Inherited from BepiColombo but must be adapted (Pointing Mechanism, coating, mounting frame), higher mass than originally budgeted
  ✓ Crucial for critical data downlink. MUST BE FOLDED REPEATEDLY.

• HEAT SHIELD with its BAFFLES, DOORS, MECHANISMS
  ✓ Openings, interfaces, diaphragms, materials - Already well underway

• AOCS SENSORS and FDIR ITEMS
  ✓ Sun Sensors, adapted Star Trackers, specific FDIR

• THERMAL CONTROL MATERIALS
  ✓ Heritage from BepiColombo? (HTMLI / Heat Pipes etc)

• HIGH SOLAR FLUX TEST FACILITY
  ✓ Moderate size, to check filters, materials, interfaces and local effects
Payload Critical Items

• HEAT REJECTING ENTRANCE WINDOW
  ✓ Development already well underway (ESA CPT)
  ✓ To be continued: IR coating cycle life improvement, mounting frame design, qualification testing higher mass than originally budgeted
  ✓ Crucial for thermal control of instrument and whole spacecraft

• DETECTORS
  ✓ Some development underway (commercial visible-light APS under ESA CTP; EUV detectors under ESA TRP)

• POLARIZERS
  ✓ Space application of LCVRs, getting going

• OTHER ITEMS
  ✓ Very instrument and design specific (e.g. specific ASIC), not underway yet, expected to be covered by Instrument teams
Science
• To study plasma processes (turbulence, reconnection, shocks) on multiple scales simultaneously

Space Segment
• 7 S/C in nested tetrahedra, optimum 12 S/C on 3 scales:
  (1) Electron scale (2-100km), (2) Ion scale (50-2,000km), (3) Fluid scale (3,000-15,000km)
• Launch on Soyuz-2b (single launch)
• Slightly adopted payload per scale (~25 kg per S/C)
• Spinning S/C with ~15 rpm
• Orbit: 10 R_E x 25 R_E (optimum science, low radiation, no debris problem) constellation passes through bow shock, magnetotail and magnetopause
• Orbital period: 104 h, Orbit Inclination: 14 degree, multiple visit of “Tailbox”
• S/C design identical for all scales to minimise non-recurring costs
• Main trade-off: dispenser / stacked configuration

Payload: provided by Member States
Cross Scale (M-Class)

Technology
• No major critical technology development required

Assessment Status
• ESA Phase 0 study completed.
• Industrial Studies – 2 parallel contracts running (TAS-F and Astrium-UK, Final Review Jun. 2009)
• In parallel: National funded Instrument Studies (10) by instrument proposers

International Collaboration
• JAXA (Scope), NASA and CSA
Science

- ~30 gram Sample Return from primitive Asteroid (C or D-type)
  e.g.: UQ 1989 (C-type), ~760m diameter, 0.67 AU x 1.16 AU

Space Segment

- Goal: Minimum possible space segment
- Launch with Soyuz -1B (Aug. 2017)
- Chemical Transfer (typ. 3.2 year), $\Delta v = 482$ m/s, Earth-Venus GA-transfer
- Arrival: Dec. 2020 – 1.6 year stay time (observation, sampling)
- Landing on target at full daylight
- Return: Nov. 2023, $\Delta v = 529$ m/s, Venus GA
- Entry: $v = 11.8$ km/s, 11 MW/m², ~76 kg entry capsule (ERC)
- 3 axis stabilized S/C, mass = 1.191 kg (wet)
- Sampling based on coring principle (some ExoMars heritage)

Payload: Focus on sample return
Marco Polo (M-class)

Technology
• Guidance and Navigation at small body, including GNC for safe landing
• Landing and operations on surface at low gravity
• Sampling mechanism and transfer system
• Re-entry up to 12.5 km/s

Status
• ESA Phase 0 study completed.
• Industrial Studies – 3 parallel contracts running (Astrium UK, OHB, TAS-I, Final Review ~ Sep. 2009)
• National funded P/L studies in parallel (23 proposals received)

International collaboration
• Under elaboration, could be with JAXA,
• In case of JAXA lead: More challenging target (e.g.2001 SG286/Wilson-Harrington)
PLATO (M-Class)

• Industrial system studies:
  ✓ Two parallel contracts, Astrium-F & TAS-I
  ‘Staring mode’ baseline from ESA study:
  ✓ Two fields of view explored (e.g. 3 yrs + 2 yrs)
  ✓ SF2-1b launch, direct transfer to L2
  ✓ 28 identical telescopes
  ✓ Total collecting area ~0.3 m², FOV > 550 deg²
  ✓ 4 CCD’s / focal plane (compatible with realistic detector procurement constraints), 3.5k x 3.5k, 18 um pixel
  ✓ Early procurement of CCD’s required in 2010

• National instrument studies:
  ✓ Single consortium in place
  ✓ Work on instrument design, performance analyses and on board data reduction
• Relevant technology activities in the current plan
  ✓ High processing power DPU (onboard processing of science data)
  ✓ Optimised high speed, high dynamic range CCD.
  ✓ High speed, 16 bit CCD signal processor / ADC.
• **Industrial system studies:**
  - Two parallel contracts, Astrium GmbH & TAS-I.
  - Feature 1.2 m telescope.
  - Focal plane instruments:
    - VIS path with large focal plane for weak lensing.
    - NIR path for accurate wide-band photometry.
    - NIR path with 3 instruments for high resolution spectroscopy.

• **National instrument studies - Two consortia are in place:**
  - Euclid Imaging, on the VIS imaging and NIR Photometer channels.
  - Euclid NIS, on NIR spectrometer channel.
Relevant technology activities in T.D.P.

- K-band down-link capability from L2 (space and ground segment).
- CCD radiation characterisation (of relevance to VIS).
- Digital Micro-mirror Device for multi-object spectrometers (of relevance to NIS, evaluation of commercial component ongoing).
- NIR/SWIR large format array detector and associated ASIC read-out.
• JAXA led mission. ESA provision: 3.5 m telescope + SAFARI instrument
  ✓ SPICA in “pre-project phase” in JAXA, 2 years Phase A study and review milestones in line with CV15-25 process.

• Industrial studies on Telescope Assembly:
  ✓ Two parallel industrial contracts: TAS-F & Astrium-F.
  ✓ Baseline design from ESA study: Ritchey-Chrétien design, ~5K operations, 700 kg, re-focussing mechanism at M2, ~5 yrs development schedule.
  ✓ Coronograph related requirements treated as delta to baseline telescope design.

• SAFARI CDF study (ESA + instrument team) completed
  ✓ Four candidates for detector technology, down-selection expected by 2nd half 2009.
  ✓ Interferometer mechanism to be traded-off.
  ✓ Instrument hybrid sorption/ADR cooler.
  ✓ Heat load budget to be consolidated with JAXA.
Relevant technology activities in T.D.P.

- Focusing mechanism for secondary mirror (3 DOF, operating at 5K).
- Light-weight mirror demonstrator breadboard (addressing specific critical areas).
- Telescope Assembly verification & Testing: demonstration of critical areas (e.g. verification of optical performance at representative temperature).
Overview of L-class Missions
IXO (L-Class)

- IXO (International X-ray Observatory) replaces XEUS (ESA/JAXA) and Con-X (US)
  - XEUS ESA/JAXA Formation Flying internal study completed
  - Mission not compatible with available CV budget

- IXO baseline for ESA/NASA/JAXA joint study:
  - Single large X-ray mirror assembly, HEW 5 arcsec
  - Deployable bench for reaching ~20-25 m focal length
  - Main instruments: Wide field imager, high resolution non-dispersive spectrometer and dispersive spectrometer using X-ray gratings
  - Compatibility with Ariane V and Atlas V launchers

- IXO internal study is just completed, with NASA and JAXA participation
  - Industrial studies should start by mid 2009

- IXO will be the input to both US decadal survey and CV L1 selection

- ESA/NASA/JAXA respective contributions and roles not yet defined
Relevant technology activities in T.D.P.

- Low mass X-ray optics (mission enabling): Si pore optics development and validation, alternative technology using slumped glass
- Cryogenic coolers (required by Narrow Field Instrument)

Technology Development Plan will be updated according to IXO re-direction and results of ongoing study

- Deployable structure required to increase focal length (extension mechanisms, deployable shroud).
- Instrument exchange platform (mechanism).
LISA (L-Class)

LISA mission
✓ ESA/NASA collaboration
✓ Measurement of gravitational wave using laser interferometry
✓ Constellation of 3 spacecrafts separated by 5 million km

Critical areas
✓ 6 drag-free test masses
✓ micropropulsion system
✓ **interferometrically** measuring variations in distance between couples of test masses at the **picometre** level
✓ **LISA Pathfinder technology validation** mission to be launched **in 2010/11**
Technology required by LISA

- Low-noise, high stability mechanisms (point-ahead and optical articulation)
- Highly stable materials for telescope assembly (CFRP, zerodur, inserts …)
- Low-noise electronic components for GRS front-end electronics (voltage references ..)
- Light sources for charge management discharge (LEDs, laser diodes …)
- Metrology system
- High-power laser system (1-2 W EOL, redundant)
- Outgassing & contamination issues
- Micropropulsion (lifetime characterization)
LISA technology

- The majority of LISA technology will be flight-validated by LISA Pathfinder (LPF)
- Main differences w.r.t. LPF:
  - lower operative frequency band (10^{-3} to 10^{-4} Hz)
  - Interferometry (polarizing vs. non polarizing)
  - Laser output power
  - Material stability (CFRP, ZERODUR …)
- Workshop on technology will be organized in Jan/Feb 2009 for consolidating Member State involvement
- CTP activities will be issued in 2008/2009
Laplace – Europa Jupiter System Mission (EJSM)

**ESA/NASA Outer Planet candidate mission**

- **ESA:** Jupiter Ganymede Orbiter (JGO), Jupiter System Science (atmosphere, magnetosphere) with focus on Callisto and Ganymede
- **NASA:** Jupiter Europa Orbiter (JEO). Jupiter System Science with focus on Europa, Io (NASA-JEO)

**Space Segment (ESA, Jupiter Ganymede Orbiter (JGO))**

- **Launch:** Ariane 5 (CSG) 2020, Transfer: 5.9 y (6.5y) VEEGA-type, no deep space manoeuvre
- **Arrival:** 2026, Jupiter insertion (12.5R_J x 224 R_J) with Ganymede Gravity Assist
- **Jupiter tour with multiple fly-bys at Callisto and Ganymede (low altitude, typ. 200 km)**
  - (1) Callisto resonant orbit, (2) Ganymede elliptical orbit (200x6000km), (3) Ganymede circular orbit (200 km)
- **Avoidance of high radiation ⇒ JGO stays <100krad (8mm) total dose, 80kg shielding mass**
- **3-axis stabilized S/C, dry mass (wet)= 1254kg (3480kg)**
- **Solar power (540W_{EOL}), array = 52 m^2, LILT technology, no concentrators, no RTG or RHU**
- **Chemical propulsion (total Δv = 2467m/s + 445m/s navigation)**

**Payload:** ~80kg science instruments, nationally provided
Laplace – Europa Jupiter System Mission (EJSM)

Technology
- Radiation hardening and tolerance / tailored shielding
- Improved Environmental modelling
- Solar Cell Technology (LILT)

Status
- ESA and NASA Phase 0 studies completed.
- ESA and NASA individual & joint reports completed
- ESA/NASA down-selection Jupiter / Saturn ⇒ Jan. 09
- Industrial Studies: start in ~ May/Jun 09

International collaboration extension
- possibly JAXA (Jupiter Magnetosphere Orbiter) and Russia (lander)
ESA/NASA Outer Planet candidate mission

- Saturn System science, Titan in-situ science (atmosphere, surface, lake)
- NASA: Titan orbiter carrying In-Situ Elements (ISEs)
- ESA: ISEs, Mongolfiere Balloon and short-live Lander
- Balloon Technology from CNES

Space Segment

- Launch by NASA, Orbiter carrying ISE’s (up to 800 kg)
- Release of ESA in situ elements after SOI at 3rd Titan fly-by
- Montgolfier: 599 kg (24 kg P/L), targeted at mid latitude (20° N), power MMRTG
- Short lived (battery) lander: 190kg (27kg P/L), northern polar lakes (Kraken Mare)

Payload: Nationally provided

- 24 kg on montgolfiere,
- 27 kg on lander
**Technology**

- Balloon (CNES) – material & inflation

**Status**

- ESA and NASA Phase 0 studies completed.
- ESA and NASA individual & joint reports completed
- ESA/NASA down-selection Jupiter / Saturn ⇒ Jan. 09
- Industrial Studies: start in ~ May/Jun 09
Technology Development Plan Implementation
Elaboration of CV Technology Plan

• Comprehensive Technology Development Plan, including ESA activities and National activities on payload
  ✓ General objective: TRL ≥ 5 before starting Implementation Phase (B2/C/D)

• Separation line between ESA and Member States for Astrophysics missions was agreed at June 08 SPC workshop
  ✓ Large and complex payload elements that are strongly interleaved with the spacecraft design remain under ESA responsibility. Example: IXO telescope.
  ✓ Focal plane instruments under Member States responsibility. Example: SAFARI on SPICA
  ✓ For cryogenic instruments, the last cryogenic stage(s) which are physically embedded in the instrument are assumed to be part of the instrument assembly

• ESA activities (subject of this meeting)
  ✓ Mainly funded by TRP/CTP technology programmes
  ✓ Work Plan and Procurement Policy approved by IPC in June/September 08
  ✓ Planning horizon: 3-4 years, up to end 2011
  ✓ ESA activities for 2008-2009 approved for implementation

• Payload National activities
  ✓ Are being consolidated with the Member States (convergence expected by June 2009)
**ESA T.D.P. content**

- **Medium Class Missions (M)**
  - High technology readiness level (supposed TRL ≥ 5, CV mission selection criterion)
  - On ESA side: No mission specific technology developments before down-selection end 2009. Pre-developments can be envisaged in the development phase, if justified by the development schedule

- **Large Class Missions (L)**
  - Ambitious long term missions, high technical complexity requiring technology developments
  - TDAs to be implemented ASAP, aiming at TRL ≥ 5 for the mission adoption

- **Future Science Programme Themes**
  - Identifed from the CV proposals by AWG, SSWG, FPAG in Oct 2007
  - TDAs to be implemented ASAP, subject to prioritisation by Advisory Bodies,
  - Technical objective: TRL ≥ 4 by next CV call in 2011, for enabling mission selection

- **Generic Technologies for Future Science Missions**
  - Multiple-use technologies required for future Science Programme
ESA T.D.P. evolution

- The activities over 2008-2009 are being implemented

- The activities in 2010-2011 are preliminary will be revisited
  - Revision expected after M-mission down-selection, beginning 2010

- More generally, the TDP will be updated regularly for reflecting the programme needs. First update is foreseen by June 09 and should include:
  - Revisit of Outer Planet activities following the down-selection
  - Solar Orbiter complement activities
  - Activities for preparing the future Exoplanet mission, following the EPRAT working group conclusions
Procurement Policy and Special Initiatives

- The nominal Procurement Policy is defined in the plan and has been approved by IPC.

- Some activities can be subject to Special Initiatives for Geo-return re-balance. Countries concerned for 2008-2009: A, CH, N and IRL.

- For Special Initiatives (S.I.) activities, the nominal procedure is the following:
  - Eligibility to S.I. will be explicitly stated in the ITT (cover letter).
  - The competition will take place as usual, according to best practices and nominal procurement policy.
  - Following the T.E.B. report, a proposal produced by a company belonging to S.I. country can be retained by the Agency, even if not ranked first, *but only if the proposal is technically satisfactory.*
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<td>IXO</td>
<td>C216-003MM</td>
<td>Bessy X-ray test facilities upgrade plan</td>
<td>DN/S</td>
<td>Q4 2008</td>
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<td>IXO</td>
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<td>Development of XEUS Si pore optics and mass production processes</td>
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<td>XEUS mirror module ruggedizing &amp; enviromental testing Ph. II</td>
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<td>GRS Front End Electronics characterization for LISA</td>
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<td>High processing power DPU based on high rel. DSP</td>
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<td>Characterisation of ultra-stable materials at cryogenic temperature</td>
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* Subject to Special Initiative TBC

Directorate of Science and Robotic Exploration
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<td>Latch up protection for COTS (Commercial, off-the-shelf) digital components</td>
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<td>Optimized electrical power conversion for RHU based systems.</td>
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Directorate of Science
and Robotic Exploration
## TDP Implementation Plan 4./6 (TRP)

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<td>Front-end readout ASIC technology study and development test vehicles for front-end readout ASICS</td>
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<td>Survey of critical components for 1 Mrad power system design including delta radiation characterisation of RH power EEE components</td>
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* Subject to Special Initiative TBC

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<td>Solar/interplanetary electron hazards</td>
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<td>Development &amp; testing of bonding and coating technologies of high temperature materials (C/C, C/SIC, ablative materials etc. ) under extreme conditions</td>
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