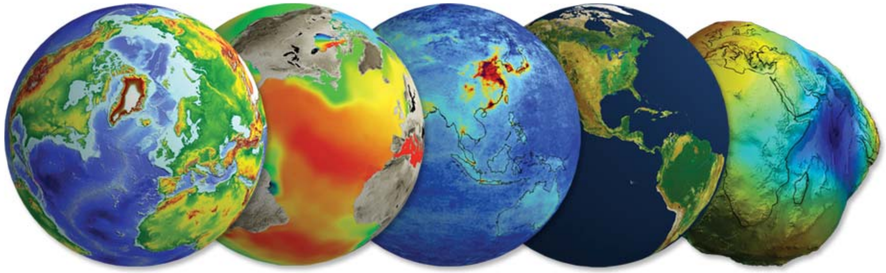
# EOEP REVIEW SEMINAR

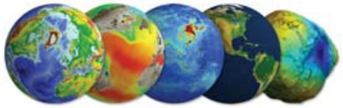
## Mission Preparation and Technology

15-16 June 2011



# Contents

1. Mission and technology preparatory activities
    - what they cover and how
    - some achievements
    - some lessons learned
2. Technology preparation and achievements
3. Earth Watch Definition
4. Instrument Pre-Development
5. Conclusions



# What do preparatory activities cover?

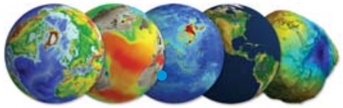
ESA’s Living Planet Strategy assigns to EOEP the task of **preparing all EO missions** until start of implementation (transition step depending on mission type), under three lines: **EOPA, EWD, IPD**

**1 - Earth Observation Preparatory Activities, EOPA:** (from EOEP Declaration and PP)

> *“single focal point for preparatory activities .. for ensuring harmonization of the many activities that lead to mission proposals ..”*

“

- *establishment of scientific objectives, including scientific studies, and of service requirements and potential partnership schemes*
- *derivation of mission and system requirements*
- *instrument, satellite system and mission feasibility or concept studies*
- *identification of critical technology requirements*
- *initiation, harmonised with other programmes, of critical technology developments and evaluations and provision of visibility to PB-EO of the overall development effort in EO*
- *establishment of IPD requirements for cost and risk reduction*
- *identification of cooperation possibilities and related preparatory studies*
- *identification of programme costs, schedules and risks and preparation of proposals for PB-EO selection*
- *architecture and concept studies for new missions and end-to-end systems*
- *supporting scientific and campaign activities*
- *supporting market evaluation activities* “



# What do preparatory activities cover? (2)

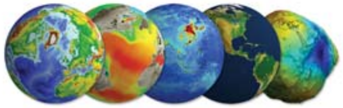
**2 - Earth Watch Definition, EWD:** (from EOEP Declaration and PP)

- *all aspects of preparation of Earth Watch type programmes*
- *classical industrial phase B studies involving Partners prepared to contribute to the mission*
- *concluding in a dossier including an end-to-end mission concept with established partnership arrangements*
- *definition and proposal of an ESA contribution to EW type programme as an optional programme*
- *undertake institutional action with partner institutions, Member States, and industry*
- *mission architecture and each of its elements are defined in sufficient detail to allow to consolidate feasibility and to estimate the cost*

*EW type missions rely upon partners (EC, EUMETSAT, industry), established user communities or their representatives for their definition"*

**additionally, in EOPA/EWD:**

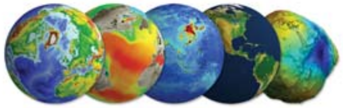
*"a funding capability .. to keep the capability to specify technology requirements and initiate technology developments specific to EO in the most flexible and efficient way, in coordination with TRD programmes"*



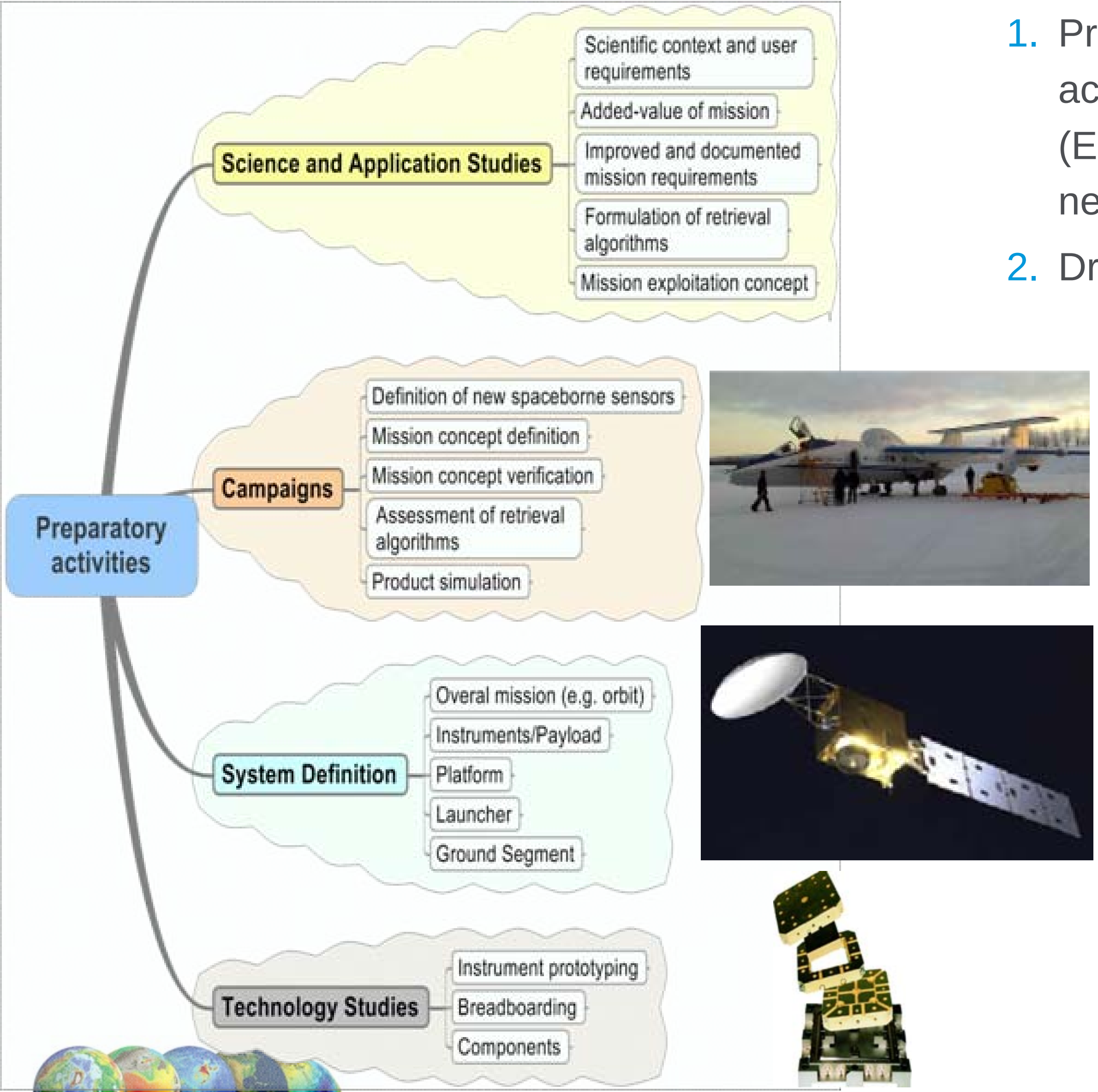
# What do preparatory activities cover? (3)

**3 - Instrument Pre-Development:** (from EOEP Declaration and PP)

- *design and manufacturing of early breadboard or downscaled version, representative of technologies, assembly and verification of full instrument*
- *for identified and agreed user-driven candidates for EE and EW type missions*
- *to demonstrate overall performance against requirements and before committing to a full satellite programme*
- *at higher level than enabling technology or demonstration of sub-systems*



# Overview of preparatory activities in EOEP



- Preparatory activities
  - Science and Application Studies
    - Scientific context and user requirements
    - Added-value of mission
    - Improved and documented mission requirements
    - Formulation of retrieval algorithms
    - Mission exploitation concept
  - Campaigns
    - Definition of new spaceborne sensors
    - Mission concept definition
    - Mission concept verification
    - Assessment of retrieval algorithms
    - Product simulation
  - System Definition
    - Overal mission (e.g. orbit)
    - Instruments/Payload
    - Platform
    - Launcher
    - Ground Segment
  - Technology Studies
    - Instrument prototyping
    - Breadboarding
    - Components

1. Preparatory activities include all necessary activities to define and evaluate future missions (Earth Explorers, (pre-)operational missions, new concepts,..)
2. Driving elements include:
   - ➢ ESA's Living Planet scientific challenges, currently as per summary in "The Changing Earth", SP-1304
   - ➢ associated observation, mission and technology requirements
   - ➢ mission preparation through Phase 0 (pre-feasibility) and Phase AB1 (feasib.)
   - ➢ foster new ideas, cooperation opportunities and prepare technologies, also for European independent capabilities
   - ➢ ESAC guidance, user communities / industry feedbacks

# What does it mean in practice?
# An example of EE Core Phase A

*Example: BIOMASS (candidate EE7 mission)*

## System (4 M)

- BIOMASS Phase A System Study (x2), addressing:
  - Space segment : payload, platform
  - Mission analysis and operations
  - Launcher
  - Ground segment
  - Critical technologies
  - Programmatics

## Technology (3.5 M)

- Large P-Band SAR antennas critical breadboard (x2)
- Very Large P-Band Antennas performance verification methodology & Facilities
- P-Band HPA technology assessment
- P-Band Reflector antenna Feed elements
- SSPA breadboard (incl. circulator/switch, power divider and calibration coupler) (x2)
- Study of P-Band transponder with ionospheric correction capabilities (x2)

## Science (1.1 M) and Campaigns (1 M)

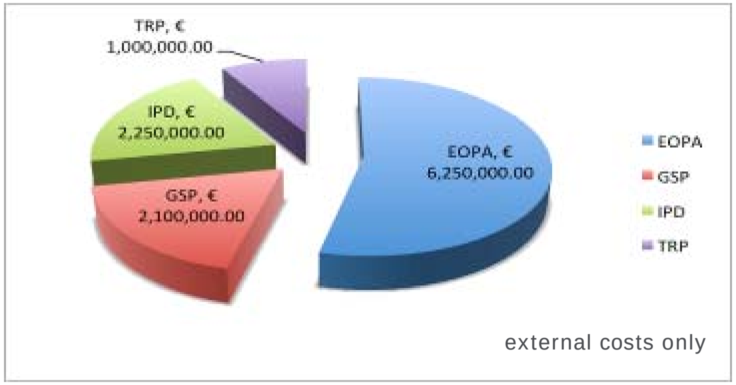
- Development of algorithms for forest biomass retrieval
- Study of ionospheric disturbance mitigation schemes
- Assessment of the BIOMASS retrieval error on flux
- P-Band SAR wave interaction and information retrieval
- Analysis of BIOMASS secondary objectives

- TropiSAR campaign (completed)
- TropiScat campaign (planned)
- BioSAR 3 campaign (planned)

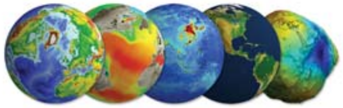
## End-to-end Performance Evaluation and System Support (1.3 M)

- BIOMASS End-to-End Mission Performance Simulator
- OpenSF end-to-end simulator framework infrastructure
- Modern attitude control of EO satellites with large flexible elements (x2)

**> 20 activities for one candidate mission!**

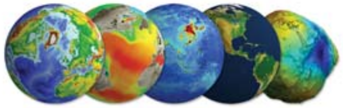


external costs only



# Approach to preparatory activities: key features

1. **End-to-end approach** with all aspects covered: science, space and ground segments, launcher, processing, end-to-end mission performance (science-engineering simulators), programmatics (cost, development plans)
2. **Array of coordinated activities**, with parallel contracts for **competition** and **alternative solutions**, however with limited resources (e.g. one study manager for two system activities and coordination of all technical activities)
3. Overall **duration driven by longer activities** (to raise technology readiness, end-to-end performance, maturing of science) and by need to ensure correct input/output across activities and synthesize results in coherent manner for final evaluation
4. Use of other funding sources than EOEP requires **actions on budget “owners”** and interactions with relevant processes (e.g. TRP 3-years planning, GSP Calls…)
5. EOEP provides **flexibility** to cover all types of activities, adding new ones as issues arise (e.g. campaigns to clarify assumptions on sensing physics), but resource limits are strict



# Preparatory activities for operational missions

Activities with similar complexity as for EE but no competition among missions

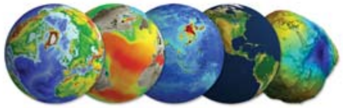
**For meteorological missions:**

- user community and relevant interfaces managed by EUMETSAT
- end-to-end mission definition and requirements under EUMETSAT responsibility

⇒ additional complexity in consolidating mission/system requirements and observation needs vs. engineering trades due to programmatic aspects, e.g. external instruments provision or cost structure

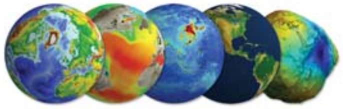
**For GMES missions:**

- definition of GMES architecture and of Sentinel missions (up to B1) driven by enhanced continuity through new observational concepts
- mission requirements from initial user requirements, GMES Service Elements, with EC
- identification of new mission needs and concepts, e.g. Sentinel-5p and Jason-CS

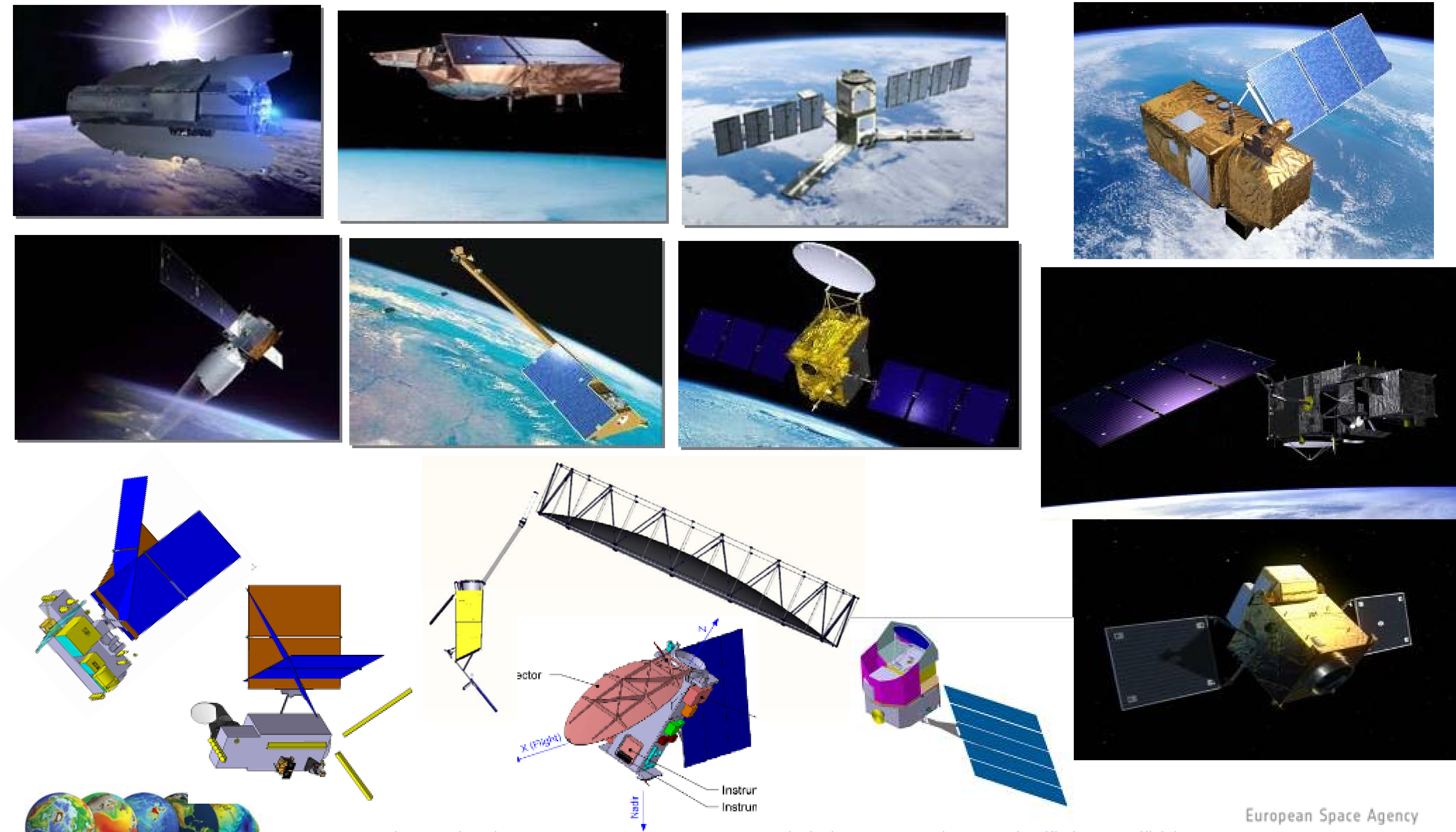


# Preparatory activities for other missions

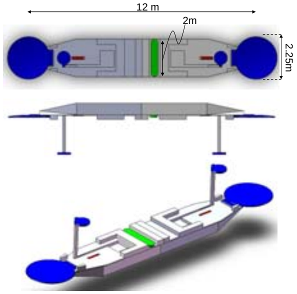
- Exploratory studies of entirely new concepts (with STSE for observation gap analyses), which often mature into: new EE proposals, concepts adopted in operational missions, national or multi-lateral projects benefitting of system/techno work,..
- Some success cases (outside EE): series of super/hyper-spectral mission studies in EWD, instrumental to define case and critical aspects for Sentinel-2 (initially not in GMES baseline); ocean EW studies supporting definition of Sentinel-3;..
- Range of mission concepts that do not (easily) fit in current perimeter of EE and operational missions, e.g. to: (1) continue observations demonstrated by EE (but are still not in meteo or GMES); (2) study climate change through very long-term monitoring; (3) serve communities spread across science and applications (e.g. TIR imaging); (4) enable commercial EO efforts;..
- ESAC recommendations for non-selected but valuable missions
- Studies of above missions, so far performed on ‘best effort basis’, should be organic part of EOEP activities

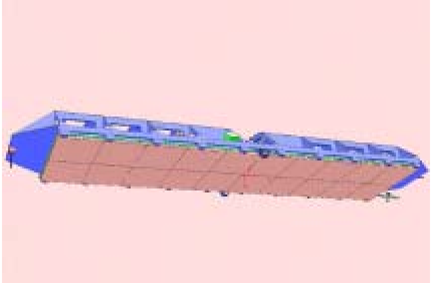


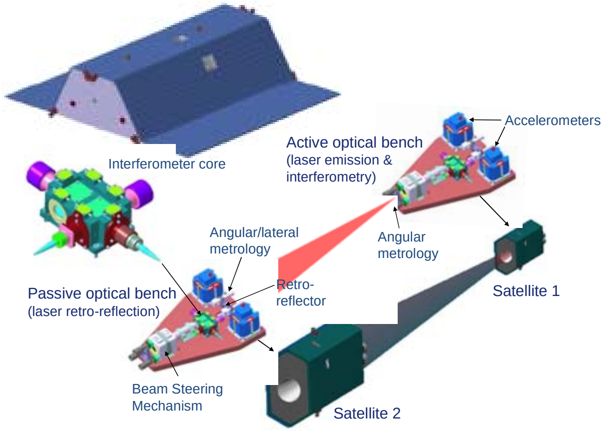
# Preparing the EO missions of ESA… (1)

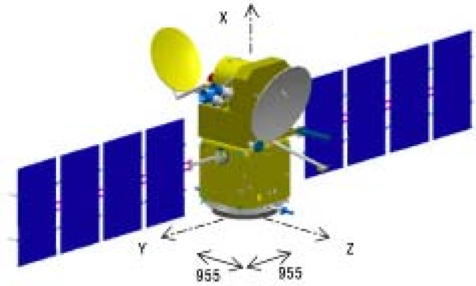


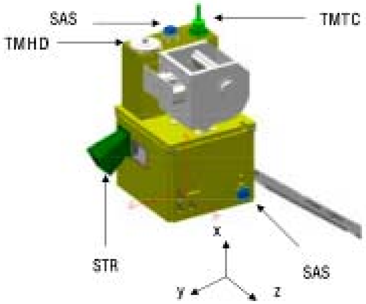
# Preparing the EO missions of ESA… (2)

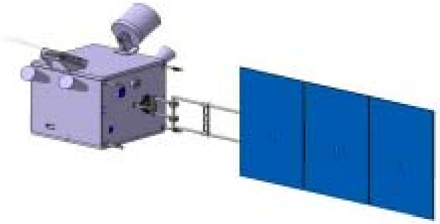


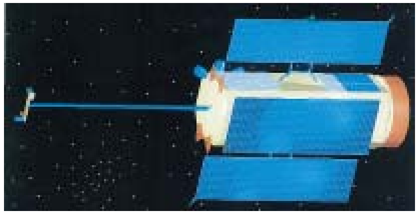


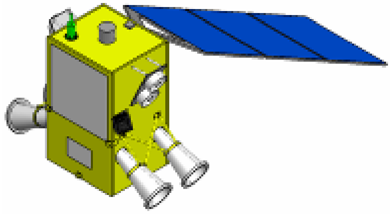


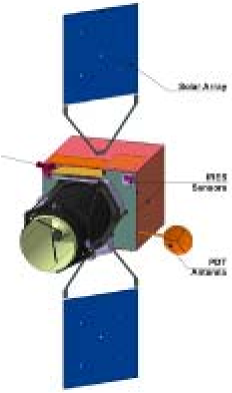


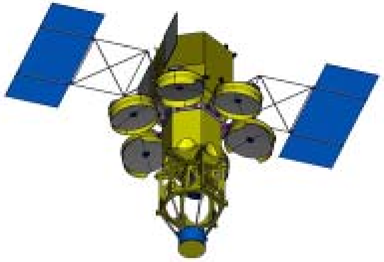


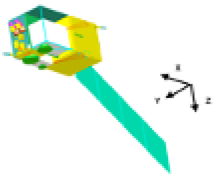


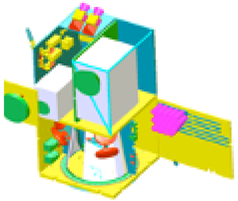


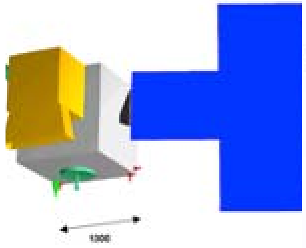


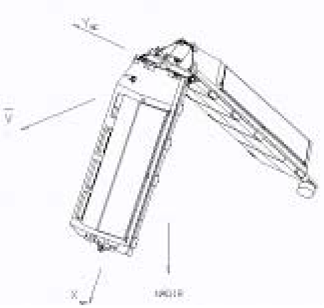






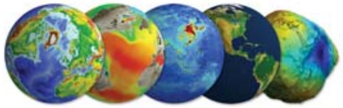






*..a subset of the mission concepts prepared to*

*deliver science and applications*
*provide long-term perspective*
*serve as international reference*
*improve industry competitiveness*



# Innovation achievements (1)

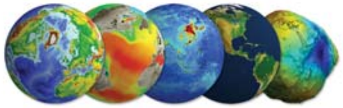
## putting Europe at forefront of EO

- EOEP advances science and applications especially through the innovative sensing techniques of the Earth Explorers (EE), e.g.:
  - gravity gradiometry (GOCE)
  - interferometric SAR altimetry (CryoSat)
  - synthetic-aperture radiometry (SMOS)
  - ultraviolet Doppler wind lidar (ADM-Aeolus)
  - magnetometry with sensing constellation (Swarm),..

- Additional innovations, improving or even adding entirely new mission capabilities, emerge during preparatory work – some examples:
  - in GOCE, active drag compensation by ion propulsion, 3D gradiometry (i.p.o. 2D), precision GNSS (independent from US), ultra-stable thermal control,..
  - in SMOS, new calibration means, high-speed optical data links,..
  - in Swarm, reducing number of satellites without science loss,..
  - in CryoSat, SAR altimetry for improved precision, solid-state altimeter,..

- Enabled by close cooperation of scientific and technical teams

⇒ **more science return, more European competitiveness**

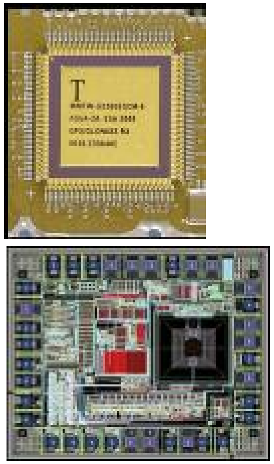


# Innovation Achievements (4)

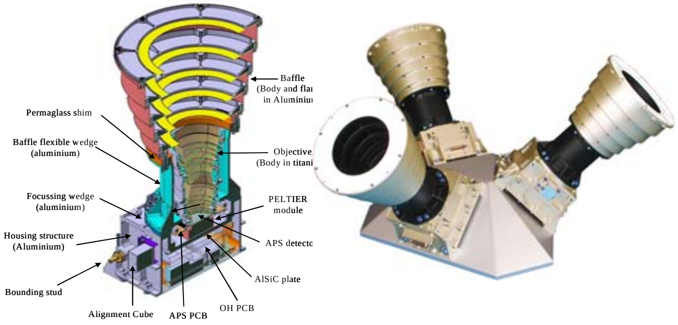
## putting Europe at forefront of EO

- Combined EOEP/TRP resources advance:
  - platform technologies, e.g.
    - technologies for higher performance receivers with new GPS / Galileo signals
    - transmission systems for multi-gigabit/second data downlinks
    - multi-head star-trackers and advanced estimation algorithms for precise gyro-less pointing with high operational robustness
    - control momentum gyroscopes for rapid attitude maneuvers (agility)
    - new modulatable electrical thrusters, incl. mini-RIT and FEEP arrays
    - mass memories with multi-terabit capacity, low mass and power
    - ...

GNSS processing chips, enabling radio occultation on MetOp and precise orbit determination on GOCE, Swarm, EarthCARE, Sentinel 1/2/3, Radarsat, COSMO,..



multi-head star tracker for gyro-less AOCS (Seosat, Sentinel-3,..)



FEEP array for ultra-fine orbit and attitude control (on-going R&D for e.g. next-generation gravity mission)

# Innovation Achievements (5)

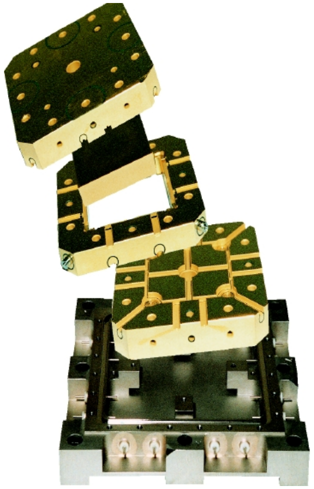
## putting Europe at forefront of EO

- Innovation is intrinsic to EOEP and benefits all missions, including operational ones, but implies large effort of technology preparation and coordination (in ESA, with Member States,..) to support all EO

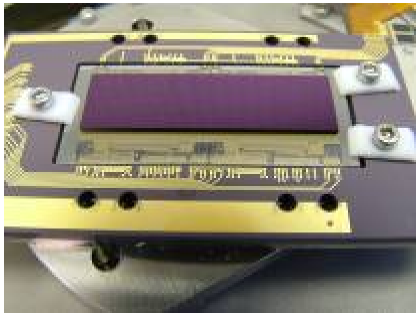
- Advancing readiness of novel technologies prior to selecting mission requires both resources and time (to mature specifications, develop to right TRL)

- R&D in preparatory phases benefit (also) other projects proposed at later EE Calls, or as EW projects, or pursued by Member States; two examples:

ESA-developed accelerometers for gravity gradiometry, enabled CHAMP and GRACE missions, before GOCE

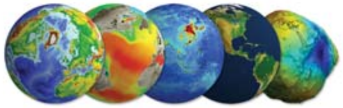


short-wave infrared detector, developed in frame of LSPIM / SPECTRA, enabled APEX (airborne), Sentinel-2, PRISMA, Sentinel-5p, HYPER-X,..



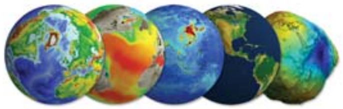
# Earth Explorer Opportunity vs. Core (1)

| | **Core** | **Opportunity** |
|---|---|---|
| definition | full-fledged research missions to advance Earth sciences and/or demonstrate new observation techniques | smaller missions to respond rapidly to evolving requirements and flight opportunities |
| modality | ESA-led mission, possibly with external contributions in kind | 1. provision to another international programme, a European national programme or another Agency programme within an agreed cooperation frame<br>2. small satellite Earth research missions<br>3. small missions to demonstrate new EO technologies and observation techniques |
| selection | Call for Mission Ideas, with indication of intended cost ceiling | Call for Mission Proposals, requesting use of mature concepts and technologies as well as stipulating a sharp cost ceiling |
| process | 1) selection for Phase 0<br>2) selection for Phase AB1<br>3) selection for implementation<br>[two User Consultation Meetings] | 1) selection for Phase AB1<br>2) selection for implementation<br>[one User Consultation Meeting] |



# Earth Explorer Opportunity vs. Core (2)

| | Core | Opportunity |
|---|---|---|
| implementation constraints | as for typical ESA satellite programmes with respect to procurement (e.g. Best-Practices), reviews, standards,.. | original goal: "implemented on short time scale avoiding the constraints of standard ESA satellite programmes"; in practice, same constraints as Core apply, apart from deviations implicit in selected proposal (e.g. industrial SMOS set-up) |
| prepared to Ph. A | GOCE, ADM-Aeolus, ERM, LSPIM, SPECTRA, WALES, EarthCARE | CryoSat, SMOS, EGPM, ACE, ACE+, Swarm |
| under development / study | ADM-Aeolus, EarthCARE, Biomass, CoReH2O, PREMIER | Swarm, CarbonSat, FLEX |
| technical complexity | high to very high: new technologies used in new ways in early Core EE; less so for EE7 | medium to high: generally, known technologies used in new ways; can be influenced by programmatic complexity (e.g. SMOS) |
| heritage from previous studies | high for all selected EE but with insufficient or discontinuous effort on critical technologies | high (for SMOS via TRP and GSTP) |



# Some lessons learned for preparatory activities (1)

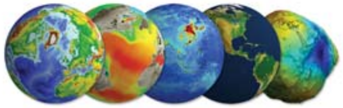
1 – mission decision at end Ph. A runs large risk of incomplete science, technical and/or programmatic consolidation, e.g. pre-developments not closed since requirements can be set only around mid Ph. A ⇒ Agency-wide move to decide after B1 will improve basis for decision (NB: NASA approves for implementation after Ph. B)

2 - early maturation of mission requirements is key to efficient preparation and requires strong(er) effort at start; end-to-end performance evaluation and campaigns, starting as soon as candidates are selected, are essential to advance all elements, including for science/processing

3 – if EE enters Ph. B, or even C/D, without TRL 5 having been reached, impacts on schedule and cost can be heavy: TRL 5 at end B1 must be proven for all critical elements based on evaluations that are factual, free of optimistic projections (e.g. “projected heritage”) and truly independent, cf. e.g. GOCE micro-propulsion, lidars

4 - critical knowledge often resides in a few key people / teams: ensuring continuity of preparation in industry and hand-over of know-how is essential to reduce risk, cf. e.g. accelerometers, AATSR/SLSTR

5- external contributions increase mission risk (potential changes, withdrawals, low visibility,..), cf. e.g. MetOp, EarthCARE ⇒ very careful risk tracking, margins



# Some lessons learned for preparatory activities (2)

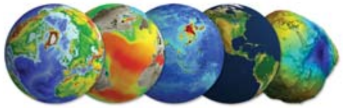
6 - stability of requirements, assumptions and technology solutions into implementation affects credibility of programmatic evaluation (and good use of preparation resources); preparation should result in frozen mission and system requirements

7 - credibility of programmatic feasibility also depends on expertise of industrial team, efficiency of consortium set-up,..; uncertainty on programmatic constraints at implementation adds risk (e.g. loss of key technical know-how): though difficult, constraints and industrial scenario evolution should be anticipated as far as possible

8 - mission design optimal when problems addressed at highest possible level, e.g. instrument issues addressed at satellite level, satellite ones at end-to-end system level

9 – need to resist technology push (e.g. GOCE superconducting gradiometer) and, where feasible, to focus techno effort on key building blocks, making industry compete so to optimise use of resources, cf. e.g. GNSS instruments, platform units

10 - mission preparation requires time, but does not suffer from 'marching army' burden as implementation – when establishing feasibility is hard, it is better to extend preparation to get more solid basis for selection (cf. EE7)



# Growing recognition of the key role of more robust preparatory activities

**Council at Ministerial Level [ESA/C-M(2008)6]:**

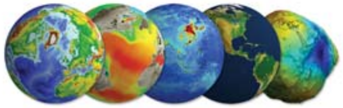
*“…ensure availability of resources for conducting two parallel pre-definition (phase AB1) studies in a systematic manner, thus offering a positive return on investment, in terms of risk reduction at later stages along the development phases of a programme..”*

**Industrial Policy Committee [ESA/IPC(2008)77 rev.1]**

*“..insufficient preparation in early programme phases reduces the committing nature and the reliability of the prime offers, which, in turn, leads to delays, cost increases and imbalances in the geo-return..*

*…to require a committing offer at a very early stage of a project implies that the risks are properly identified and mitigated , that the TRL level of the key elements is sufficient and that the interfaces are stable. This can only be achieved if sufficient funds and time are invested in early phases of a project. Recent examples demonstrate that this was not the case in all of the Agency’s projects…*

*Reinforcing the early phases of projects (AB1 up to SRR) would allow two potential primes to submit committing bids. This will be achieved by allocating more resources to early phases of projects.*
*In addition, returning to a policy of having two contracts in parallel for early phases would not only increase competition but also have the advantage of developing technical alternatives, elements of which can later be combined. “*

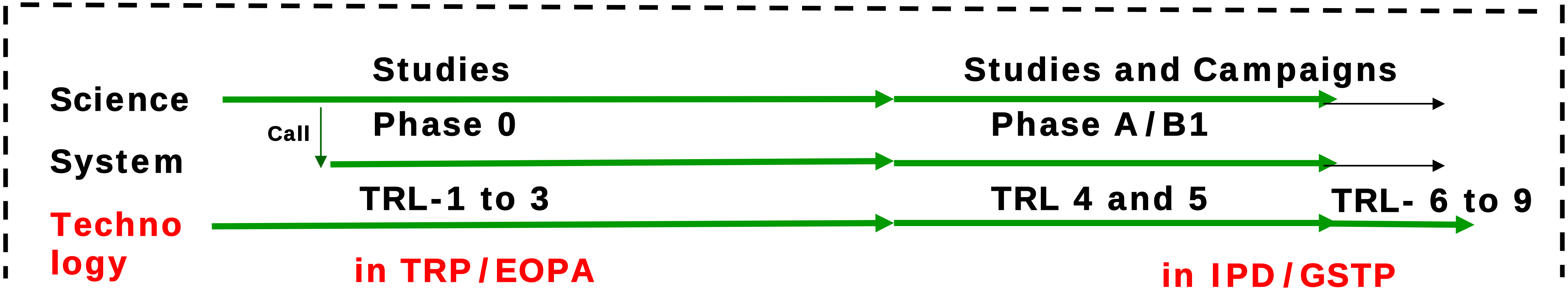


# What are the risks of insufficient technology preparation ?

At **low TRL** [enabling technologies, early prototyping]: immaturity at initial selection (and through early phases), limiting proposals of new mission ideas

At **high TRL** [representative breadboards, critical sub-systems]: mission immaturity at approval and implementation

*in either case, the knock-on effect is an increase in the risk of delays and cost over-runs*



*cf. DOSTAG Chair report to PB-EO (Nov 2010) on the consequences of the mismatch between needs and resources for technology preparation*

# ESA End-to-End Technology process

**Goal** (partly achieved): drive all technology programmes by requirements defined with and for the users (EO, telecom,..) aiming at:

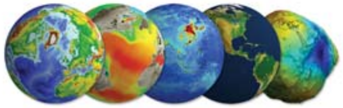
1. Preparing the technologies for future projects in a timely manner
2. Stimulating technology innovation
3. Supporting European industry competiveness
4. Ensuring European non-dependance on critical technologies

ESA's technology programmes:

- at corporate level : **TRP** (15 % of TRP budget for EO), **GSTP** (*a la carte* programme)
- at EOEP level : **EOPA/EWD** for early developments (TRL 1 - 3) on instruments and for EO platform technologies at TRL 1 – 5

  **IPD** for higher TRLs to mature key instrument subsystems or full BB for planned or candidate missions

very helpful process but no panacea..



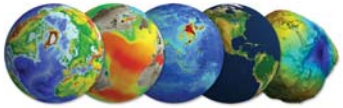
# Earth Watch Definition: adapting the concept (1)

One of the most successful EOEP efforts, having
(a) prepared a.o. meteo missions, e.g. MTG, MetOp SG, GMES architecture and dedicated missions, impact studies,..,
(b) contributed to robust system-of-systems with new features or key inputs (e.g. multi-satellite meteo systems, new GMES dedicated missions)

EW concept was interpreted in wide sense, indirectly helping to prepare new missions in national, multi-lateral and industrial contexts

Various mission concepts do not fall under EEs or meteo/GMES, e.g.: missions demonstrated by EEs but not yet adopted in operational systems (precursors), gap-filler missions, missions rejected as EE but commended for value in science/applications,..

Synergy exists with activities on exploitation and operations, e.g. initiatives on volcanic ash monitoring or on new (higher level) products for long-term monitoring



# Earth Watch Definition: adapting the concept (2)

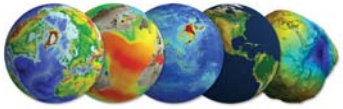
Need for exploratory studies for future operational systems, based on anticipated user needs and technology evolutions, e.g. on use of GEO systems for hi-res imaging or microwave sensing for meteo, future ocean observing systems (incl. post-Jason altimetry as per EUM-ESA Roadmap)

Studies of concepts from cross-fertilisation of research and applications, e.g. for hyper-spectral imaging, systems based on constellations and formations (e.g. *a la* A-train)

EWD can also support:

- early-TRL technology developments for future operational systems, complementing any TRP/GSTP efforts
- EOP involvement in EO initiatives within other ESA programmes, for e.g. focussing of science/applications, harmonisation with other missions,..

Although initial idea of PPP-type EW missions was premature, the need remains to support industry to strengthen its worldwide competitiveness in EO: technology-oriented co-funded developments, after open Calls, could support industry, particularly that in new or under-return MS



# Instrument Pre-Development
# The initial objectives

## EOEP Declaration (extracts)

*...for identified and agreed user-driven candidates for EE and EW type missions*

*...to demonstrate overall performance against requirements and before committing to a full satellite programme*

TRL 4-5

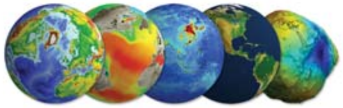
*...IPD is an activity at higher level than enabling technology or demonstration of sub-systems*

*...design and manufacturing of early BB or down-scaled version, representative of technologies, assembly and verification of full instrument*

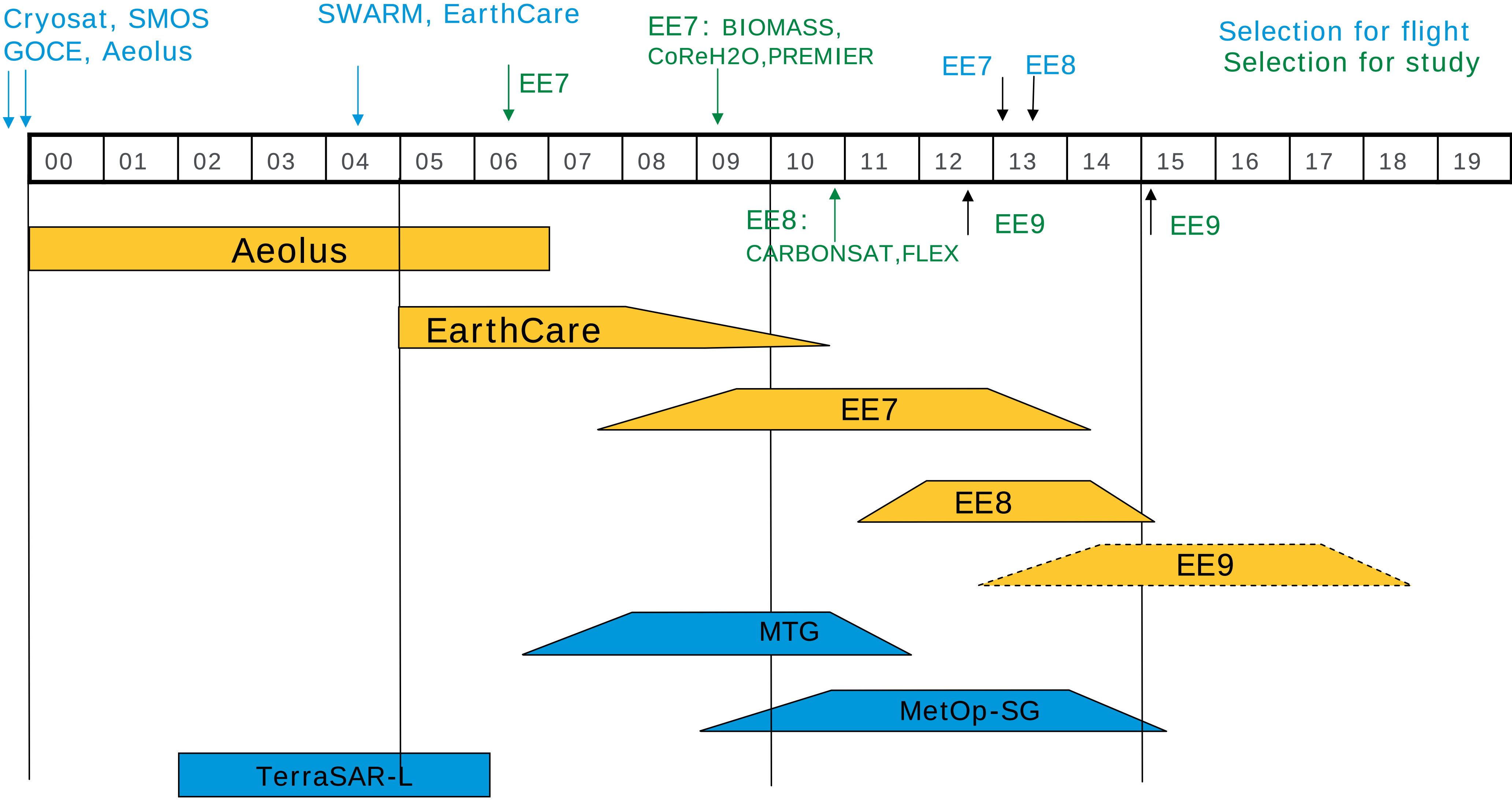
## EOEP PP: ESA/PB-EO(98)14, rev.1 (extracts)

*...fill the gap in instrument development strategy, in complement to techno research programmes*

*...If the instrument is such new or difficult that there is a shortage of available experimental data, the objective could be the construction of an airborne version*



# Pre-developments are user-driven



Cryosat, SMOS
GOCE, Aeolus

SWARM, EarthCare

EE7

EE7: BIOMASS,
CoReH2O,PREMIER

EE7 EE8

Selection for flight
Selection for study

00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19

EE8:
CARBONSAT,FLEX

EE9

EE9

Aeolus

EarthCare

EE7

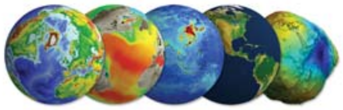
EE8

EE9

MTG

MetOp-SG

TerraSAR-L



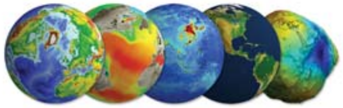
# Instrument Pre-Development definition: The evolution

1. Initial idea:
    - Explorers are selected in pairs (e.g. Cryosat-SMOS, GOCE-Aeolus, SWARM-EarthCARE)
    - 2nd higher-risk mission goes in pre-development phase (cf Aeolus and EarthCARE)

2. Initially, early selection of single instrument contractor possible
    - Focus on single instrument “Pre-Development Model” (cf Aeolus)

3. Evolution of procurement policy to promote competition
    - Starting with EarthCARE, parallel pre-developments
    - Predevelopments focus now on equipment and components

4. Longer study phases imply more upfront investment, spread on all parallel instrument concepts

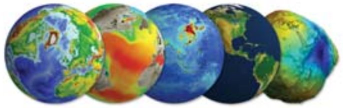


# Instrument Pre-development definition: The current mechanism (1)

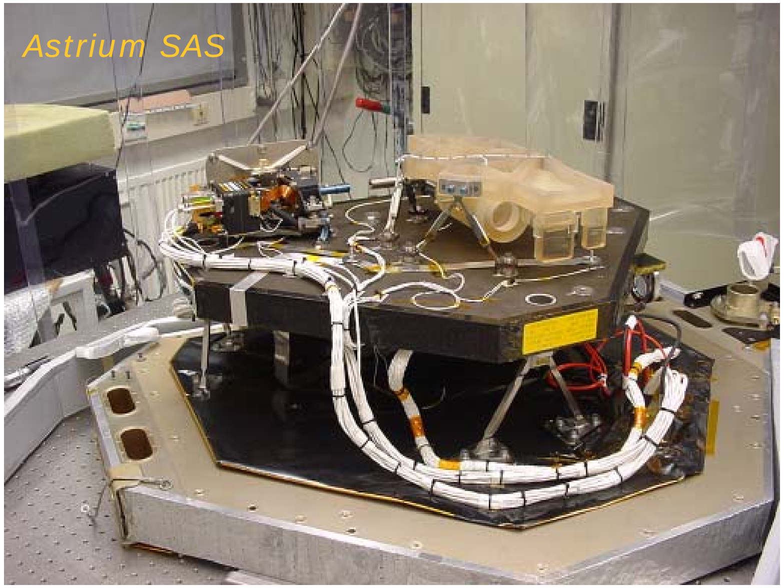
1. Identification and classification of programmatic and technical risks for new instruments, according to results of phase 0 and phase A

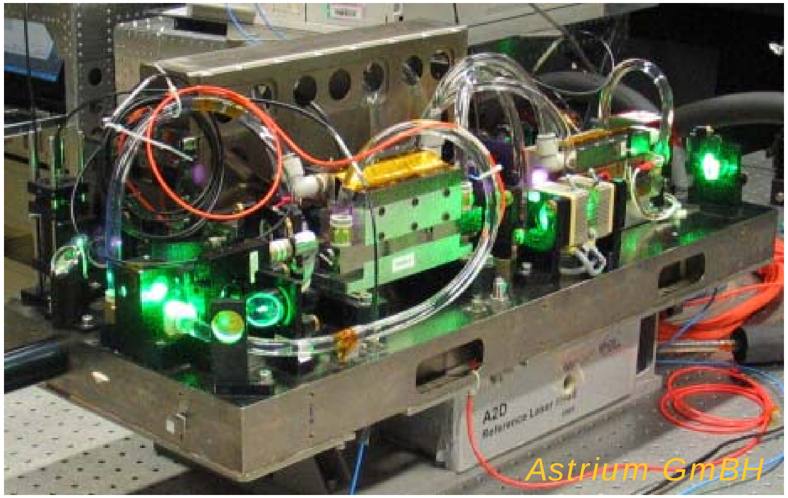
2. Definition and implementation of risk reduction and supporting technology activities
   a. Progressive involvement of IPD in complement of (TRP) technology activities in phase 0
   b. Bulk of investments initiated in phase A (after PCR)
   c. Emphasis on critical equipment at TRL 4-5

3. Transfer of final development results to project implementation phase (B/C/D)



# Early achievements
# Aeolus

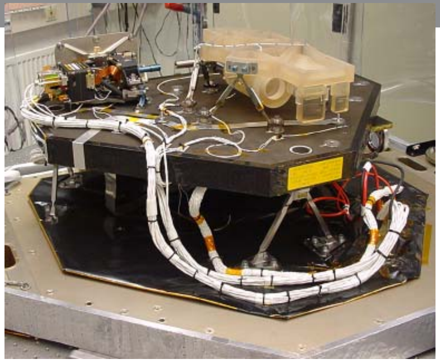


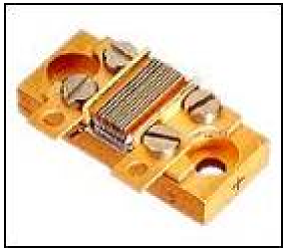


Airborne ALADIN demonstrator (A2D)

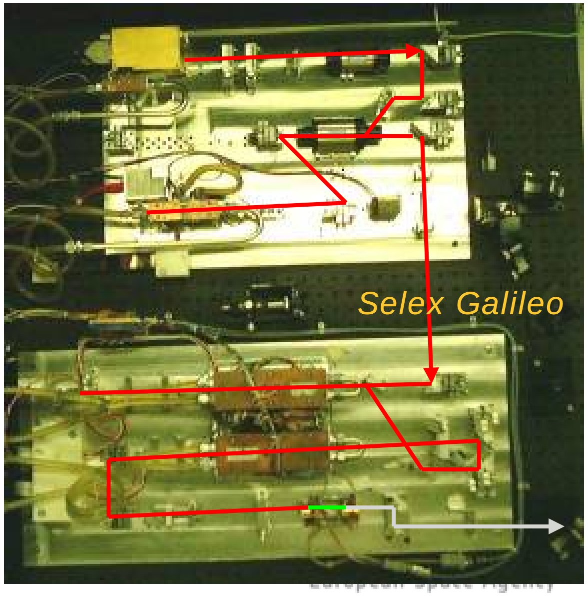
# Aeolus with hindsight….

1. Initial risk analysis
   a. Feasibility and performance of direct-detection receiver
      - Full Pre-Development Model ✓
      - Reuse in airborne instrument ✓
   b. Reliability of laser diodes
      - Assessment of diode stacks and optimisation of manufacturing processes ✓
   c. Performance of laser, particularly burst-mode
      - Two Breadboards at TRL4 ✓
      - Reuse in airborne instrument ✓
2. How about Laser-induced damage and laser stability ?
   - Underestimated, thought to be “simple” engineering X





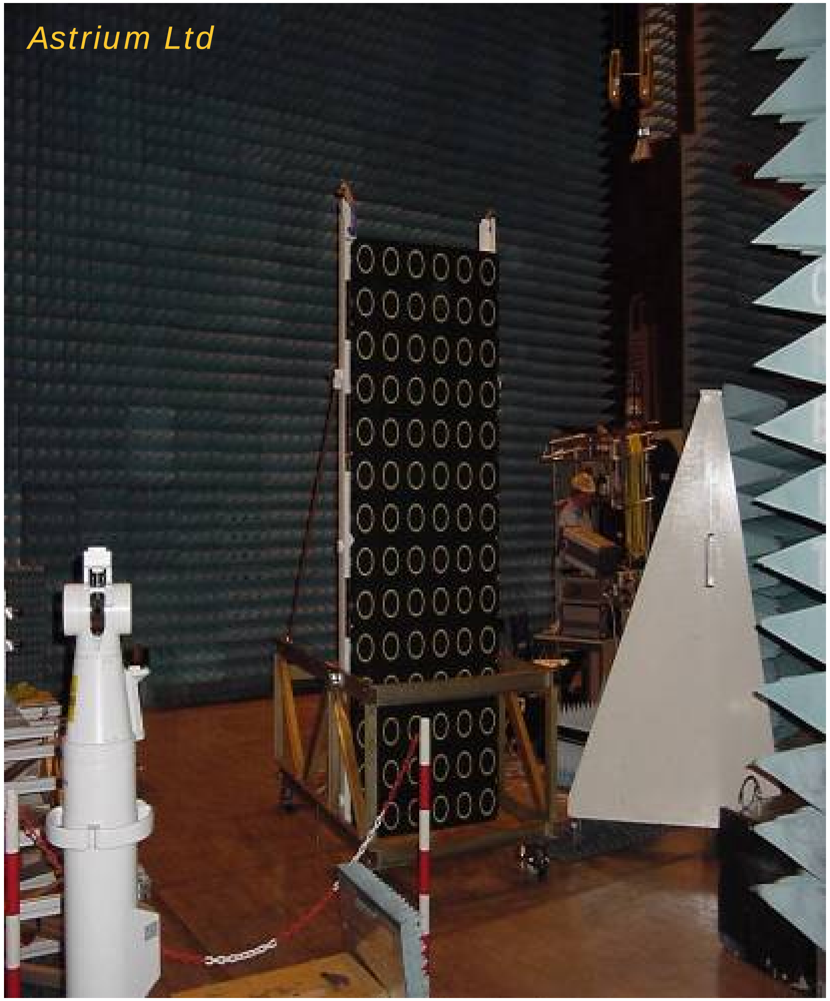
*Quantel Diodes*



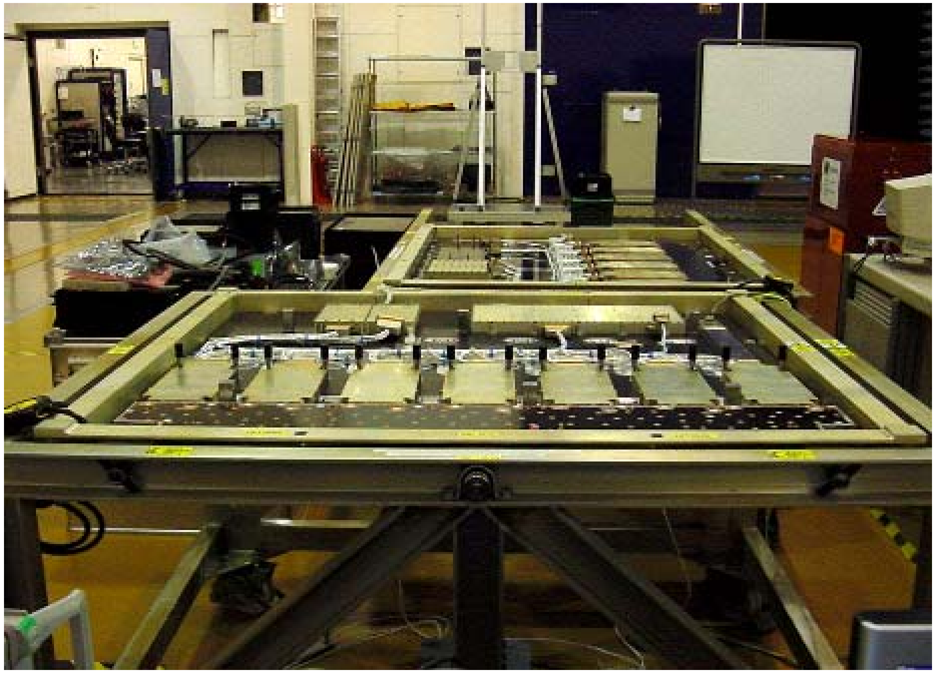
*Selex Galileo*

TRL 4 is not enough

# L-band SAR (TerraSAR-L)

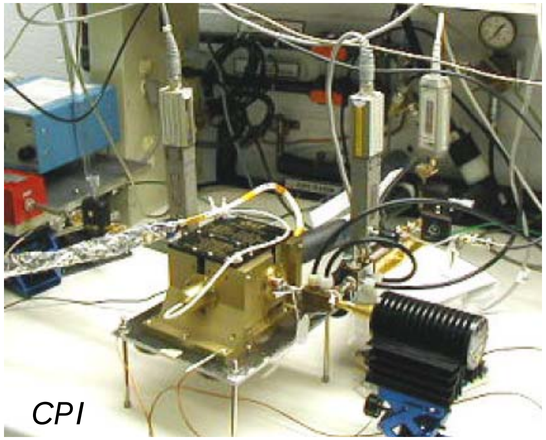


Front side of SAR panel with radiating elements

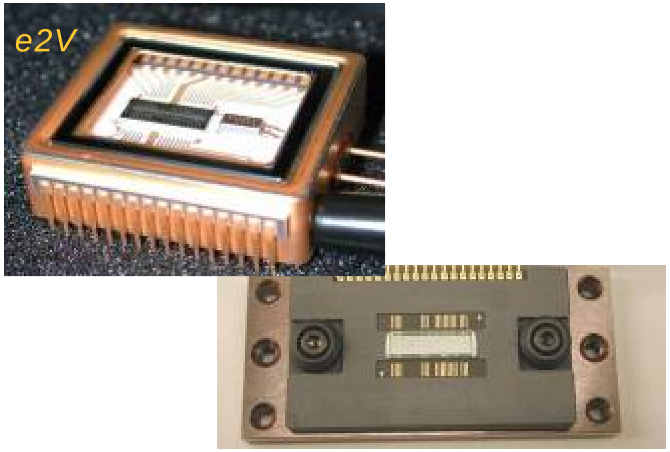


Back side with T/R model, distribution network and control

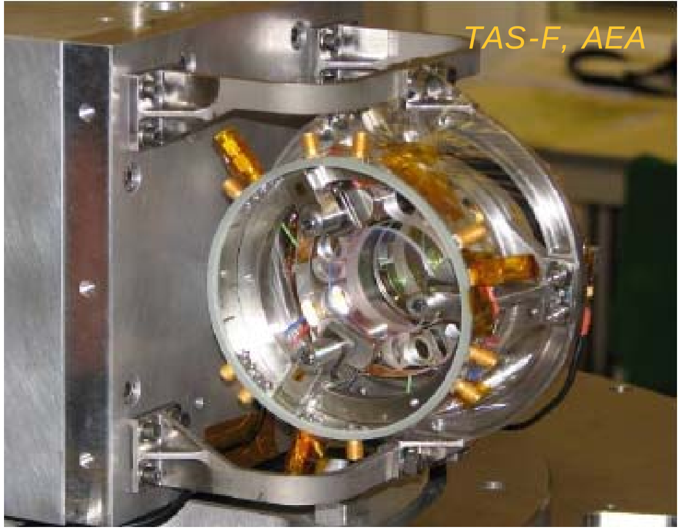
# EarthCARE



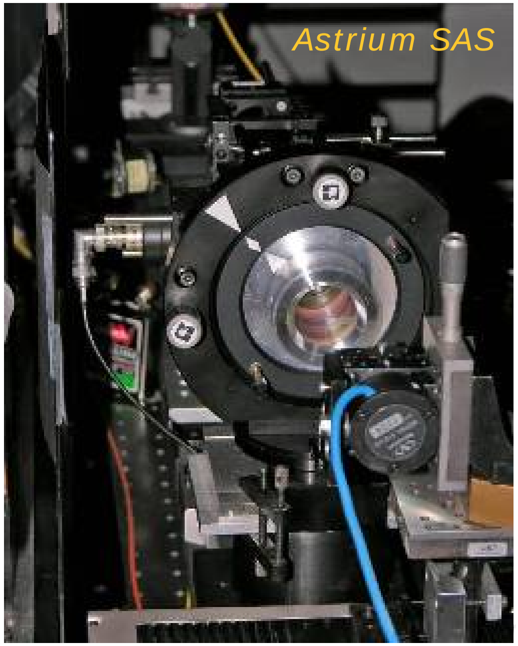
Klystron life test (CPR)

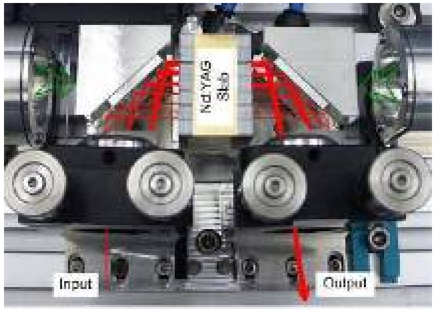


L3 and Memory CCD (ATLID)

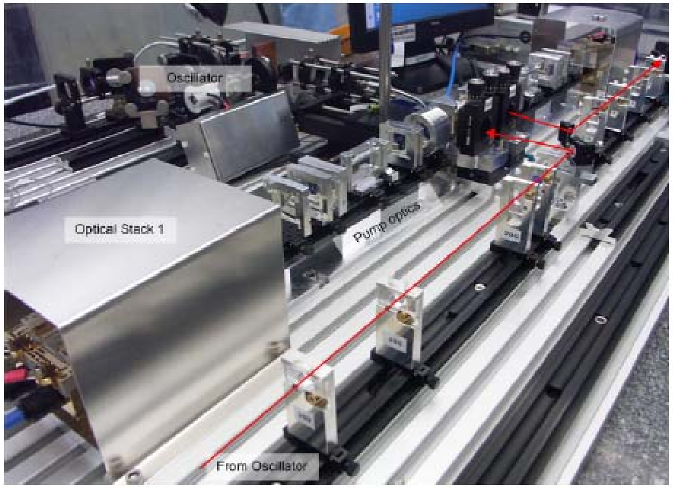


High-res filters (ATLID)





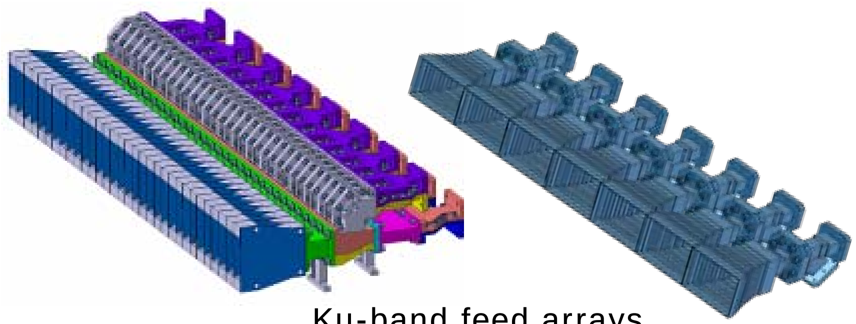
Laser BB (ATLID)



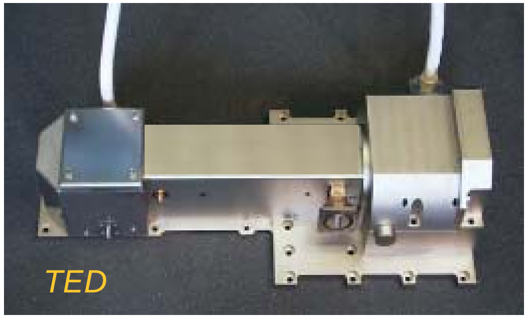
*Astrium GmBH + ILT*

# Earth Explorer 7

## CoReH2O



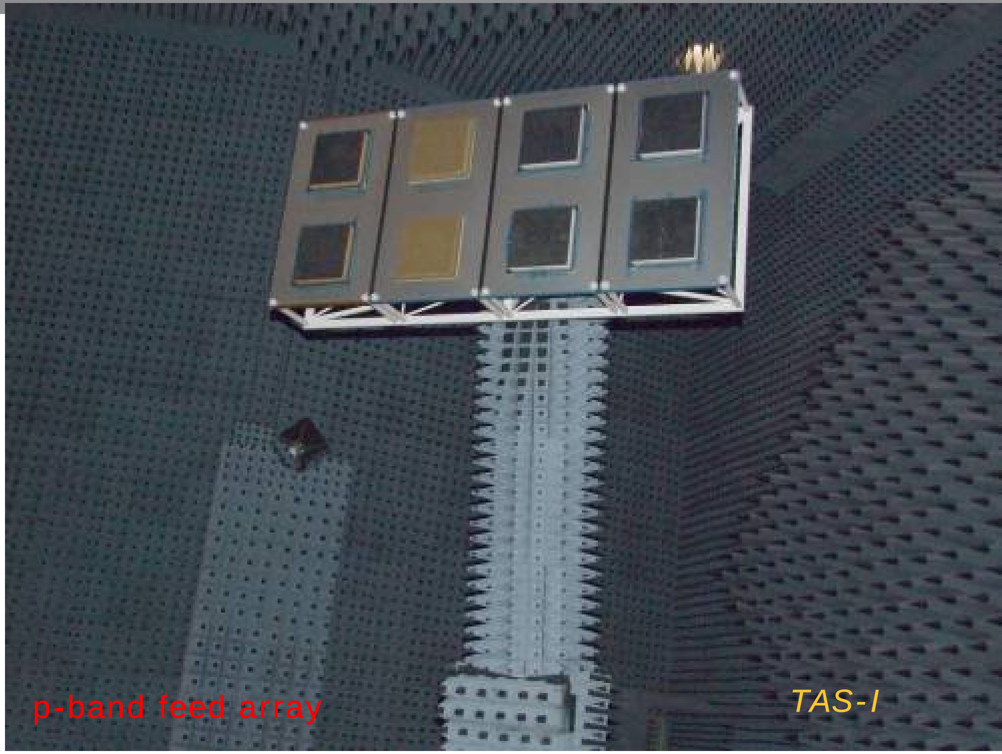
Ku-band feed arrays

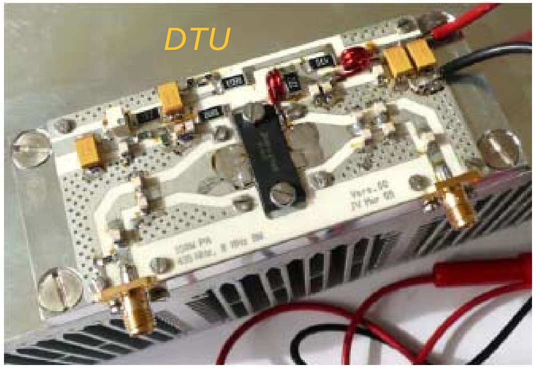


X-band Travelling-Wave Tube Amplifier (SAR-Lupe?)

Ku-band Extended Interaction Klystron

## BIOMASS





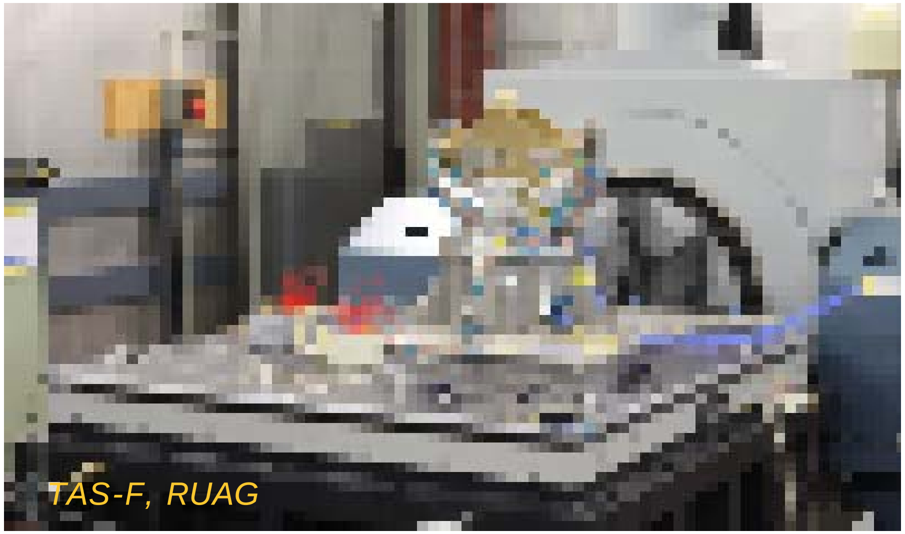
P-band LDMOS HPA

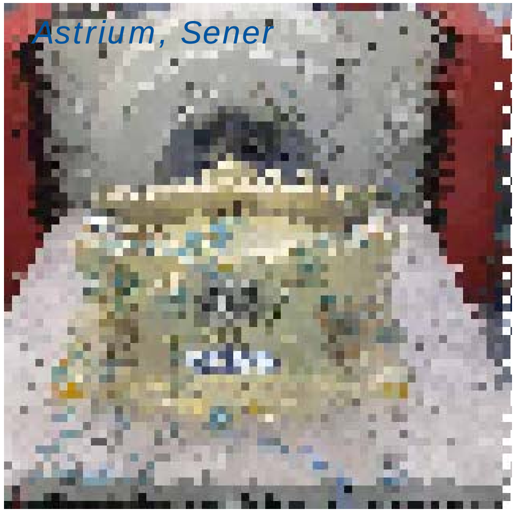
# Meteosat Third Generation (1)

High Power 50 K Stirling cooler (cold finger)

Large 50 K Pulse-tube cooler

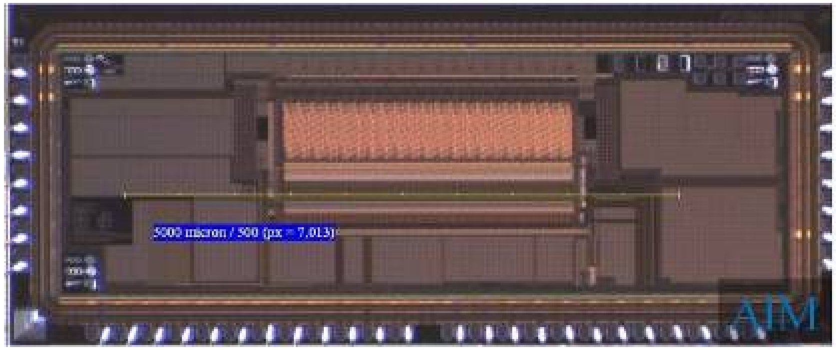
Scan mechanisms



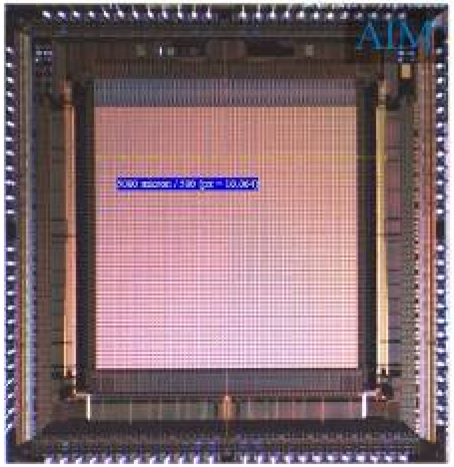


*Confidential*

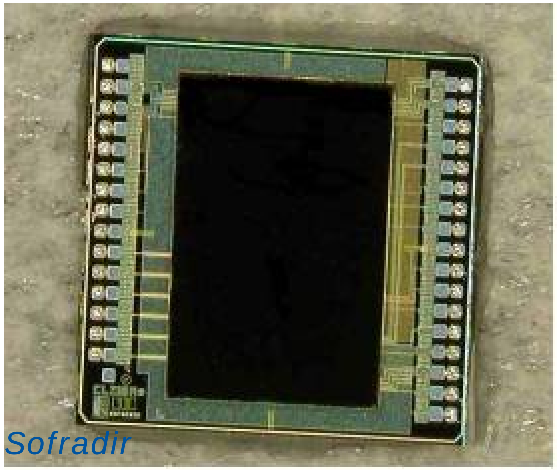
# Meteosat Third Generation (2)

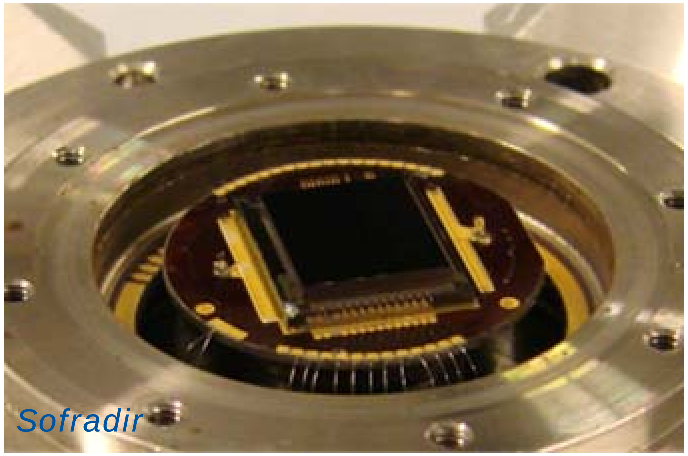


FCI IR 13.6 “test vehicle”



IRS LWIR “test vehicle”





# And more in the pipeline…
# MetOp-SG

*Astrium SAS, Omnisys*

54 Ghz backend spectrometer

*RPG*

In the plan:

- Reliability assessment of diodes, LNAs, mixers…
- MicroWave Imager scan mechanisms
- 3MI breadboard

# Airborne instruments (1)

## APEX: hyperspectral imager

With PRODEX

## A2D: Doppler Wind lidar

# Airborne instruments (2)

*RAL*

MARSCHALS: mm-wave limb sounder

*DTU*

POLARIS: P-band ice sounder

SNOWSCAT: X- to Ku-band scatterometer

*Gamma RS*

# Some spin-offs

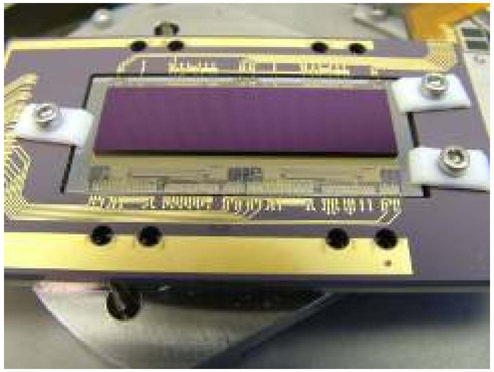

JenOptik

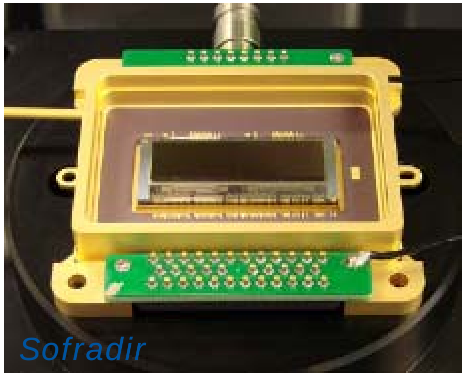

Quantel diodes

Laser diode stacks (Aeolus,EarthCare)

⇩

All lidar missions

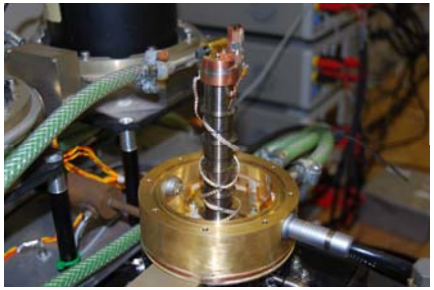



Sofradir

Short-Wave IR detector array (APEX)

⇩

Spirale, PRISMA, Hisui, S5P ...
(and also ENMAP)

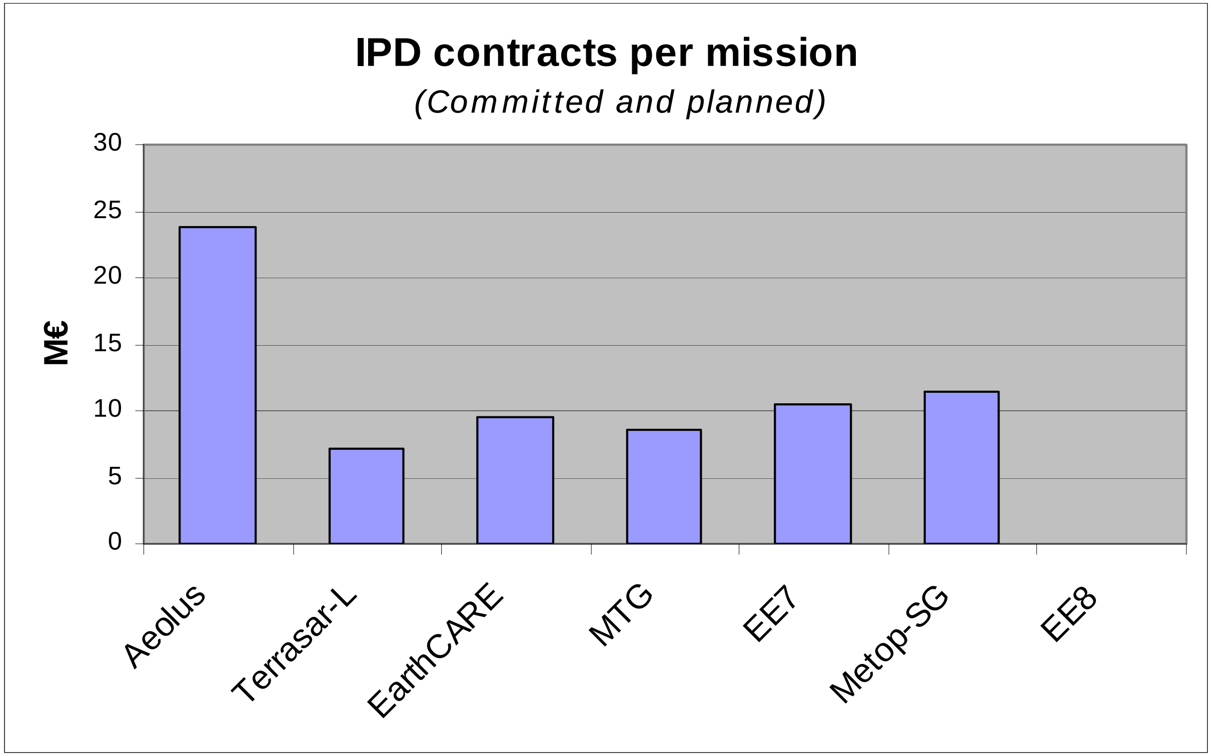


50 K coolers (MTG)

⇩

CSO, MetOp-SG,...

# Investment per mission



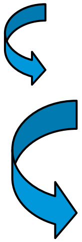
Contract values in different ec conditions

| Mission | Aeolus | Terrasar-L | EarthCARE | MTG | EE7 | MetOp-SG |
|---|---|---|---|---|---|---|
| # supported instruments | 1 | 1 | 2(x2) | 2 (x2) | 3(x2) | 4 (x2) |

# IPD: Lessons learned (1)

1. Pre-development of hardware at TRL 4-5 takes time
   - Typical time-scale 2-3 years
   - 10 years for complete programme on laser diodes

2. Pre-development of hardware at TRL 4-5 is expensive (€ and manpower)



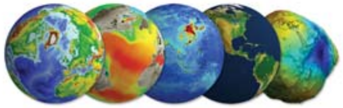
   - System procurement policy: long parallel study phases
   - few generic pre-developments, many parallel pre-development of competing instrument concepts
   - Limited and decreasing resources are diluted, leading to insufficient risk reduction

# IPD: Lessons learned (2)

3. TRL 4 is not sufficient
    - …but sometimes TRL5 cannot be achieved in time (e.g. cryocoolers)

4. Criticality analysis is … critical
    - Underestimating remaining schedule or technical risk, either in phase A or later pre-development, can be fatal
    - Concepts can change when phase B starts (geo return, industrial constraints)

5. IPD could not anticipate needs and support advanced developments of ambitious instruments,
    - Example: missions commended by ESAC, not selected because of technological difficulties
    - Process to be invented to define user-agreed advanced pre-developments?

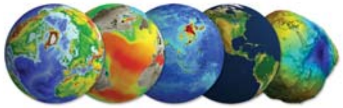


# IPD: Achievements vs expectations

1. Did IPD serve user requirements?
    - IPD follows mission definition and selection process

2. Was IPD appropriately coordinated with other preparatory and technology programmes?
    - IPD is strongly coupled to EOPA & EWD
    - IPD activities take full account of TRP/GSTP activities

3. Did IPD adequately reduce mission risk before implementation ?
    - IPD is the indispensible gap-filler between basic technology and project implementation
    - All considered missions have been addressed
    - Dispersion of resources on many instrument concepts limits risk reduction efficiency



# Block 1 conclusions

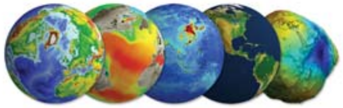
1. Mission and technology preparation under EOPA, EWD and IPD played a crucial role to achieve scientific and technical excellence of ESA EO missions and enhance European competitiveness

2. The main objectives of EO preparation were met, as shown by the track record, though several lessons had to be learned especially on technology aspects

    a. EOEP flexibility was used to somewhat alleviate resource limitations; however, more resources are needed to secure more robust, credible and early preparation of all missions, in particular to achieve the required technology readiness

    b. Focusing the preparation on a lower number of selected EE candidates in Ph. 0/AB1 will also help

    c. Systematically advancing early concepts and EO technologies, allowing time-critical developments, will support the ambitions of the EO community



# THANK YOU