# Balancing Science and Engineering

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European Space Agency

# Science Instrument Funding

- Generally the spacecraft and common systems are provided by ESA, the instrumentation by Member States
- In principle a competitive AO process, but often a single consortium comprising many nationalities provides the instrument(s)
- In the past a problem that the key instrumentation would not be developed on time, resulting in expensive delays
- Science Programme Review Team (2007) recommended no mission should go to “adoption” for production phase until adequate Technology Readiness Level was demonstrated
- Means there is a competitive study phase of ~4 missions in parallel until end phase A
- We have now a “Catch-22” because member states unwilling to commit to instrument development until a mission is selected, in case the investments do not provide a return

# The new process

- Cosmic Visions has several described several “themes”
- ~Biannual calls for Medium (1 year budget) or Large (2 year budget) missions covering Astronomy, Planetary and heliospheric physics in these thematic areas
- Pre-phase A to define payloads in some detail, then studied with industry and proto-instrument consortia to confirm schedule, cost and feasibility and a competitive selection
- After selection the implementation phase typically can take 7+ years with various drawn out milestones reviews
- Missions are breaking budgets!
- Per planet or astronomy wavelength band there is only possibility for <1 mission per decade

# Science Teams

- Typically the Agency appoints an advisory Science Team from the pre-Phase A  Study through until operations
- The make-up changes according to their commitments, conflicts and skill sets. Can be from PIs and/or community scientists, depending on the flavour of the mission
- Chaired by Project Scientist, reports to the Science Programme Committee but not powerful when the implementation contract starts
- A key responsibility is to provide a “YELLOW BOOK” that should sell the science case (contrast the internal ESA technical assessment report)
- ***Define, elaborate and defend science requirements***
- Need to respect the geographic interests of payload and industry
- ***If the engineering constraints define a reduction in science goals then the Science Team should provide the advice to the Director***

# Project Teams

- Management Team at ESA is an engineering team that follows and manages the industry contracts, whereas the science support department in ESA only has oversight of operations and little input to the hardware implementation
- Mainly cost and schedule focussed
- *Bus driver to get a spacecraft to orbit! Not necessarily interested in final in-orbit science products*
- Excepting how to define hand-over point and finalise the industry payment
- The best PMs are motivated by the science product and will engage with payload teams to leverage any critical development solutions

# Payload Consortium

- Select proto-consortium(a) before phase A to elaborate the instrument designs and work in parallel with industry
- Ensures that schedule and costing understood by member states before mission adoption
- Supposed to ensure that the technology development plans are already under way to ensure an acceptable TRL before adoption
- However this requires a substantial commitment from funding agencies, as well as the academic team, before the mission is even selected.
- Lots of bitterly disappointed scientists (eg MarcoPolo R)

# Science Requirements

- Level 0 e.g. “Determine Equation State of Neutron Stars”, “Return a pristine sample of solar system primordial material”
- Level 1  e.g. “Measure the M-R relation of 10 NS to accuracy 4%”, “Measure the turbulent pressure support in intracluster gas via. velocity broadening to <100km/s”
- Level 2 – very specific science measurement programmes and observations, leading to instrument science performance requirements e.g. “Effective area at 1keV of 1m$^2$ “, “Total noise in 200s exposure of 5 electrons r.m.s.”

# From Science to Engineering

- Then leave engineers to interpret and translate Level 2 science requirements into engineering requirements
- The engineering requirements can be implemented in hardware - engineers supposed to create new implementations cf. the proposed ones from science PIs
- We are learning this decomposition process is very difficult, but if a good decomposition occurs it can carry across the whole project phase
- However there are many difficulties when the scientist has a particular implementation idea
- Preliminary Requirements Review as part of selection process
- **Experiment Interface Documents**
- **Science Management Plan**

# Conflicts during Design and implementation

- Mission lifetime – a lifecycle cost driver, from operations as well as demonstrating hardware durability. Impacts observing programmes
- Observability – pointing constraints (solar aspect angle, communications) can reduce the accessibility of targets that compromises the assumed mission duration
- Payload safeing – radiation events, spacecraft contingencies can force design changes that modify the instrument and its operations
- Communication – ground station availability, link budgets can affect the data rates assumed, payload health monitoring and also the cadence of commanding new observations
- Mechanisms – swopping between instruments, scanning optics, doors, filters are life-limiting or single point failures and are avoided
- Data proprietary rights, calibration and PR issues can impact the protocols for operations

# Other science institute involvement

- Earth Observations – all instruments industry built to specifications
- They tend to have science organisations under contract for roles such as performance simulations etc.
- Under science directorate, putting the load of operations onto member states as a cost-saving measure.
- Also facilitates seamless (?) transition for instrument knowledge to operations
- But cradle to grave problem – e.g. XMM-Newton in orbit for 14 years and universities cannot sustain the effort and skill base over that time