THE ISS AND ESA'S FUTURE SCIENCE AND TECHNOLOGY

Malcolm Longair
University of Cambridge

Chair: ESA High-level Science Policy Advisory Committee (HISPAC)

THE ROLE OF HISPAC

- The Committee was set up by the Director General of ESA in 2007 and reports directly to him. He has emphasised that science is both a flagship and a symbol for the Agency.

- The vision is to promote a "one-ESA" and "one science programme", an Agency-wide coherent and comprehensive approach to science and technology as a whole.

A SCIENCE-LED ONE-ESA

- The term *science-led* encompasses a very wide range of activities within ESA. It includes pure science, applied science and science related aspects of technology.
- There is a *very fine line between science, applied science and technology* in many aspects of ESA activities. Science without an in-depth appreciation of advanced technologies and technological capabilities is not feasible. Likewise, technology without input from some of the most imaginative European scientists lessens the capability for innovation in both science and technology.

WHAT HISPAC SHOULD AND SHOULD NOT DO

- The DG has emphasised the importance of developing themes which are of clear relevance for the benefit of the citizens of Europe and the world community.

- At the same time, HISPAC has a responsibility to engage with issues in fundamental science and curiosity-led research which may have a very much longer pay-back time for both science and society than more obviously societally oriented themes.

WHAT HISPAC SHOULD AND SHOULD NOT DO

- The remit of HISPAC is to reflect upon interdisciplinary science and technology themes and ideas *"unconstrained by considerations of funding, ESA's internal Directorate structure, the existing approved programme and politics"* (Decree of the DG).

- The considerations should refer to long-term science and technology developments and beyond the time-scale of the currently approved programmes. The considerations, however, have impact on a much shorter time-scale because of the need to prepare for opportunities in the longer term.

MEMBERSHIP OF HISPAC

Ad Personam Malcolm Longair, (UK) (chair), Tony Pratt (UK), Helmut Grassl (Germany), Amabile Liñán (Spain), Catherine Cesarsky (France), Tilman Spohn (Germany)

Ex officio Chairs of the Science Advisory Committees – Willy Benz (SSAC), Berndt Feuerbacher (HESAC), Alan O'Neill (ESAC), Gerhard Beutler (GSAC)

Observers David Williams (Chair, Council), Richard Bonneville (Chair, SPC), David Parker (Chair, PB-HME), Per Erik Skrøvseth (Chair: PB-EO), Agnès Grandjean (Chair, PB-NAV), Jean-Pierre Swings (Representative of ESF, chair of ESSC) .

In Attendance Director General and Executive

HISPAC Coordinator Marc Heppener

IN ATTENDANCE

Director General and Executive

Director General Jean-Jacques Dordain

DG-C Karlheinz Kreuzberg, Head of ESA Director General's Cabinet

Directors (with direct science/technology involvement)

Franco Ongaro, Technical and Quality Management (D/TEC)

Thomas Reiter, Human Spaceflight and Operations (D/HSO)

Volker Liebig, Earth Observation (D/EOP)

Didier Faivre, Galileo and Navigation-related Activities (D/NAV)

Alvaro Giménez Cañete, Science and Robotic Exploration (D/SRE)

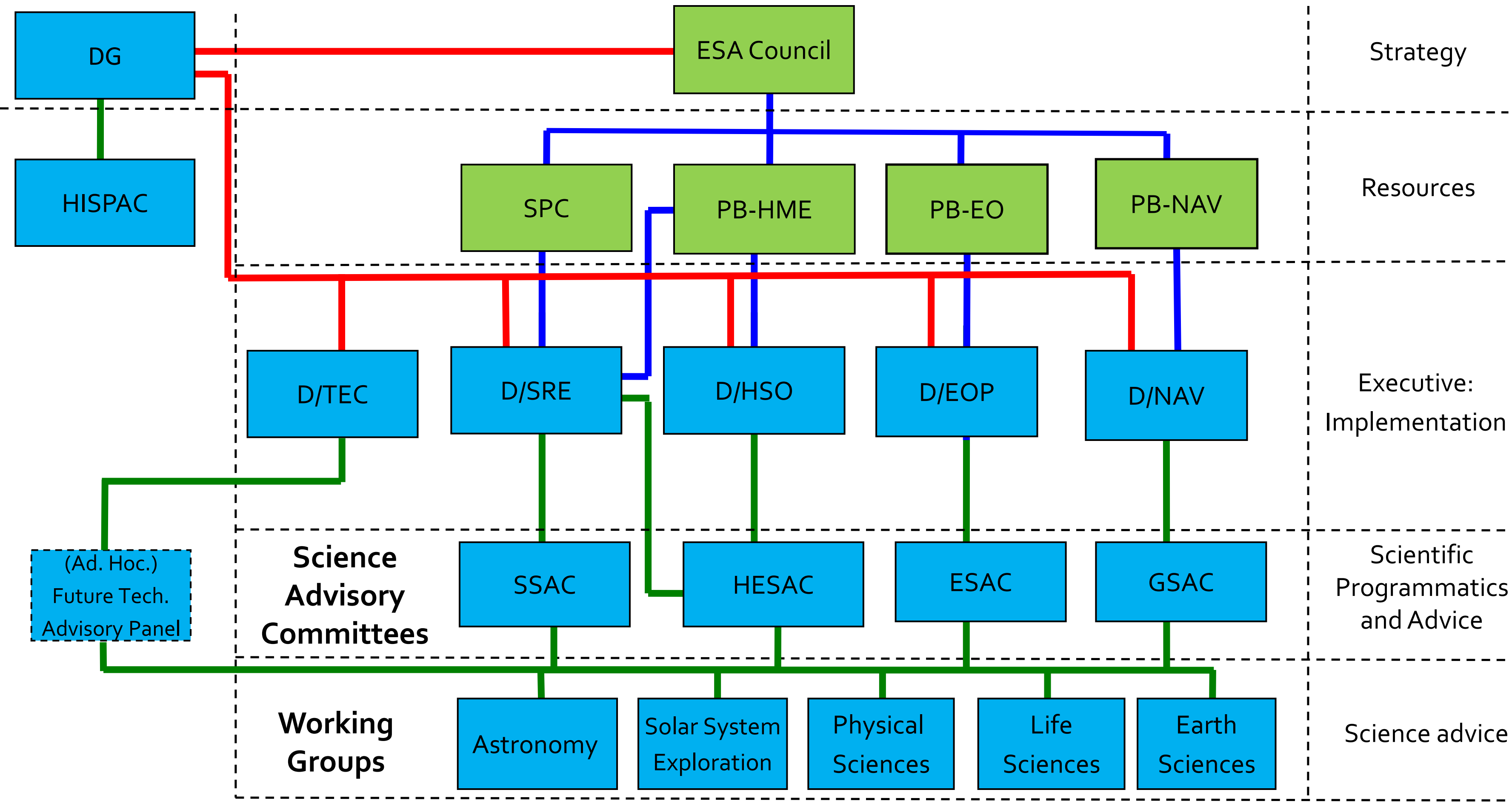
Giuseppe Morsillo, ESA Policies, Planning and Control (D/PPC)

SCIENCE ADVISORY STRUCTURE OF ESA PROGRAMMES

- The Director-General agreed, on the recommendation of HISPAC, to implement a new science advisory structure which seeks to implement the vision of a *science-led ESA, maximising synergies across all science and technology activities of the Agency*. The result will be a coherent and comprehensive science policy with homogeneous interfaces to the scientific community.

- The new structure has been implemented, taking account of the need to reconstitute the committees and set up new operating procedures.

The Science Advisory Structure of ESA Programmes



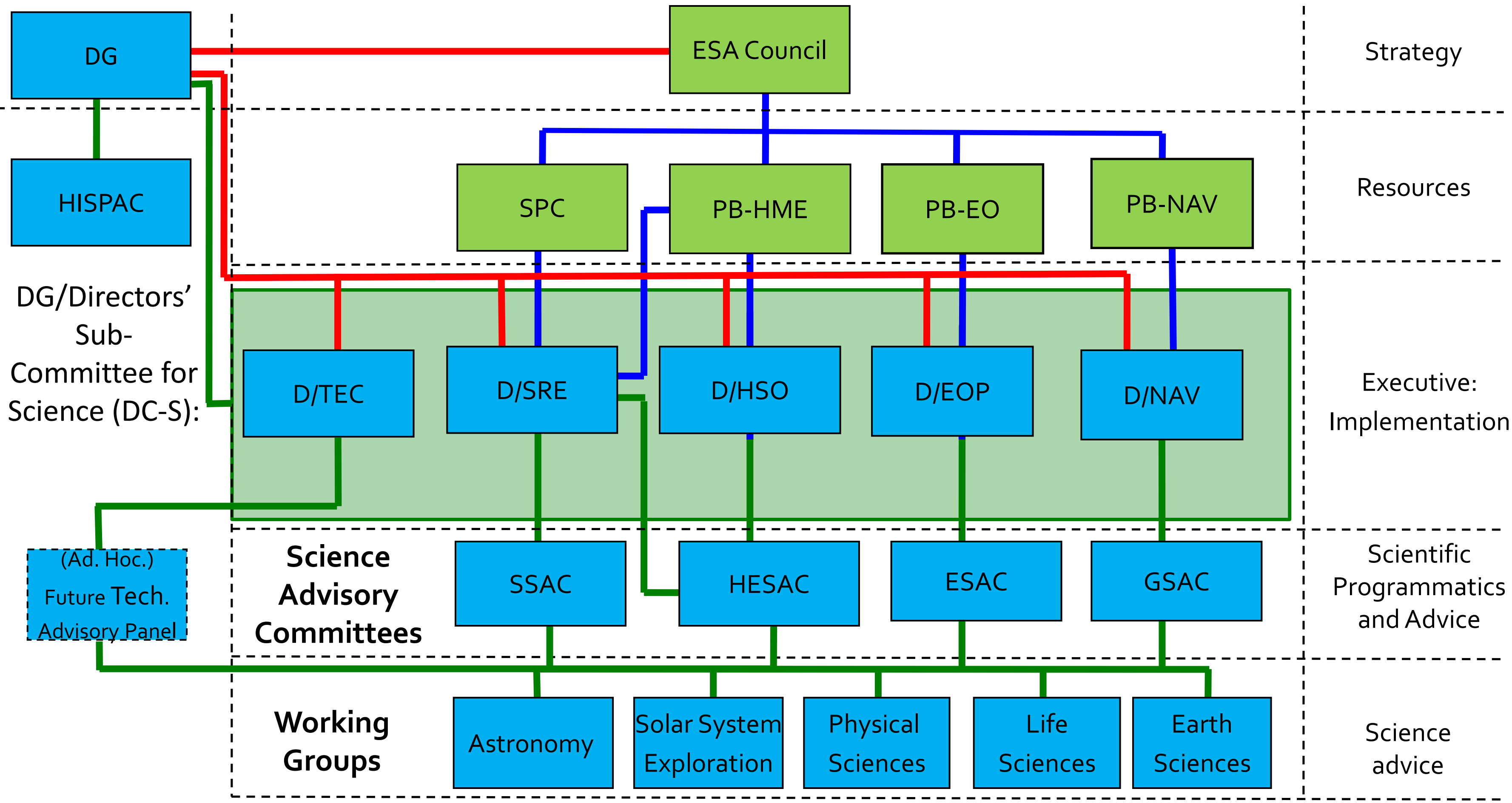
Red lines
Appointments

Blue lines
Resources

Green lines
Advice

The Structure was implemented in 2010 and continues following the reorganisation of ESA which took effect from 1 April 2011

DG/Directors' Sub-Committee for Science (DC-S)



DC-S is chaired by the DG and includes the Programme Directors D/SRE, D/EOP, D/HSO and D/NAV, as well as D/TEC, D/PPC and DG's Cabinet. The Chairman of HISPAC is invited as observer for non-Executive items.

FOUR GRAND SCIENCE THEMES

- In preparation for the November 2012 Ministerial Council Meeting , HISPAC has been charged with preparing a ‘horizontal’ analysis of the long-term grand science themes and enabling technologies.
- The grand science themes span the whole of the ESA programme and indicate areas in which synergies between science and technology across all the Directorates provide added value and enhanced collaboration on common themes.

GRAND THEME 1. COSMIC CLIMATE

- Earth Observation – the climate of our planet
- Solar System missions – the study of ‘life’ under extreme conditions within our solar system.
- Exoplanets – a unique opportunity to study large samples of planetary systems with quite different planetary atmospheres from those within the solar system.
- Habitability and extrasolar planetary systems.
- Galileo satellites and the continuous global monitoring of the Earth’s ionosphere and atmosphere.

GRAND THEME 2. UNDERSTANDING GRAVITY

- Definition of time entirely by precise clocks in space.
- The mass distribution in the Earth and the planets, potentially by gradiometry using atomic interferometry
- Testing General Relativity by orders of magnitude better precision than at present.
- New generation clocks with the objective of accuracy 10^{-18} using atomic clocks and frequency combs.
- Materials under zero gravity - 'classical' fluid physics and materials sciences. Study of materials at the quantum level under zero gravity.
- Gravity and the origin of the large-scale structure of the Universe, leading to the testing of General Relativity on the largest scales.
- Tests of strong field General Relativity in the vicinity of black holes and the very early Universe .
- Detection of Dark Matter, Dark Energy and antimatter; undulations in the fabric of space-time
- Detection of gravitational waves.

GRAND THEME 3. LIFE IN THE UNIVERSE

- The formation and evolution of chemical elements, galaxies, stars and planets
- Pre-biotic molecules and origin and evolution of life in the Universe. Life signatures/condition. Extremophiles/adaptation strategies, life under extreme conditions within our solar system.
- Environmental conditions in planets and exoplanets.
- Water in the Universe, understanding planetary systems, planetary and exo-planetary atmospheres, oceanography, global change
- Role of gravity in development and functioning of organisms
- Conditions in the early Earth, life migration.
- Radiation biology, integrated human space physiology, space psychology, human performance under extreme conditions
- Impact of human exploration on individuals and society (including Earth applications of space research)

GRAND THEME 4. COSMIC MAGNETISM AND HIGH ENERGY PARTICLES IN SPACE

- The local space environment and the protection of astronauts, including magnetic shielding.
- The physics of cosmic rays, including the very highest energy cosmic rays .
- The origin of cosmic magnetism
- Very-high energy physics with very-low temperature atoms.
- Magnetic signatures in Cosmic Microwave Background observations

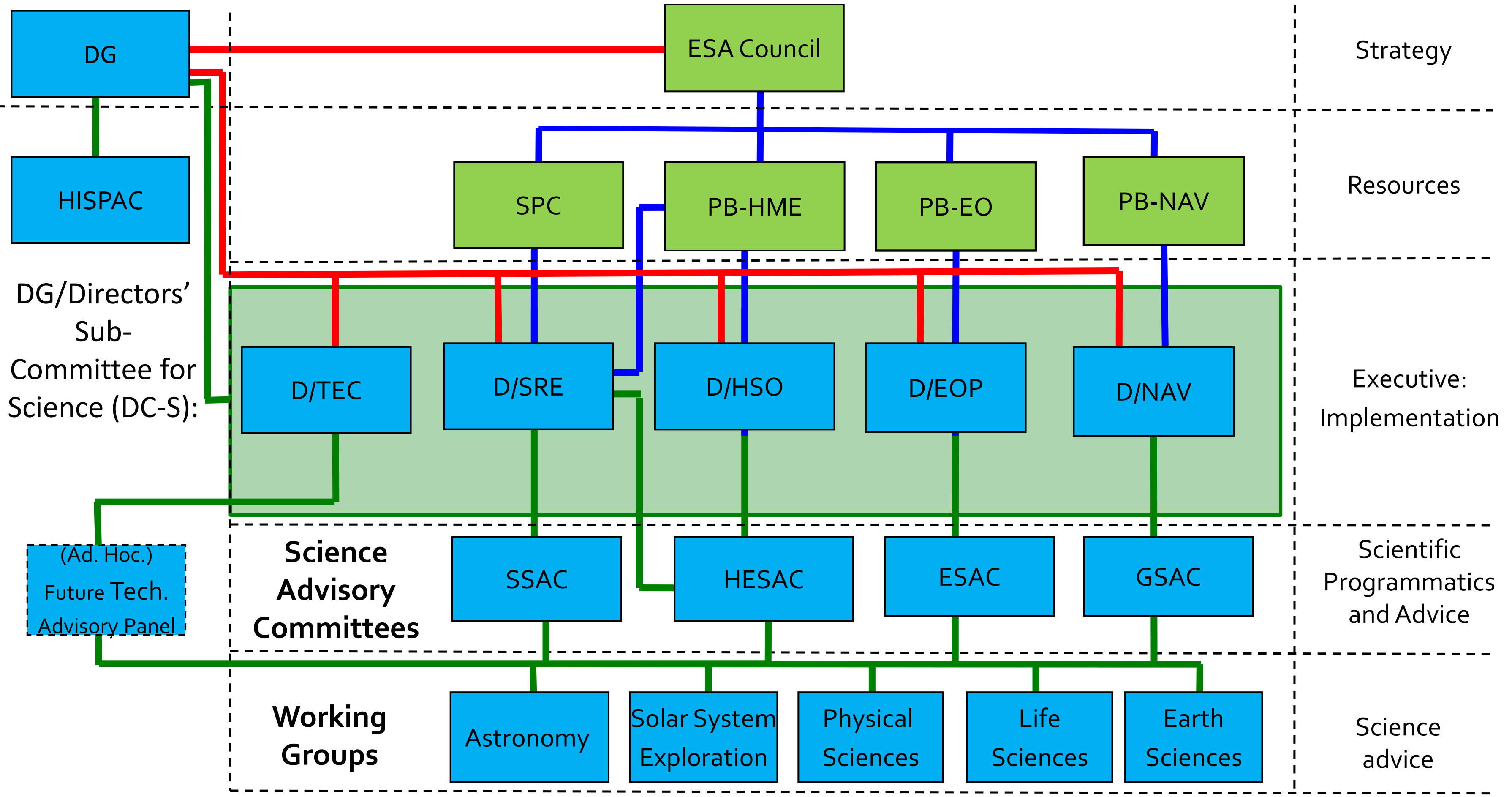
ADDITIONAL SCIENTIFIC CHALLENGES OF ‘FAR OUT’ OBSERVATIONS

- Out of the Ecliptic missions
- Space Situational Awareness
- Comet/asteroid riders
- Hibernation
- The challenges of space travel beyond Jupiter, propulsion and communication
- Going beyond the bounds of the solar system, Sun as a gravitational lens

ESA FUTURE TECHNOLOGIES COMMITTEE

- To monitor future science and technology requirements of the science and applications projects discussed by the WGs and the SACs beyond the missions already selected as candidates.
- To identify areas in which innovative technologies should be explored by the community of scientists in the Universities and Institutes and awarded study contracts by ESA.
- To make specific proposals for implementation in the areas of advanced future technologies.
- To respond to the needs of the broad science goals set by HISPAC for the future science and technology initiatives.
- To develop their own ideas and concepts which are likely to be important for future ESA projects.
- Initiatives to be developed in full collaboration with D/TEC.

Future Technology Advisory Panel (FTAP)



DC-S is chaired by the DG and includes the Programme Directors D/SRE, D/EOP, D/HSO and D/NAV, as well as D/TEC, D/PPC and DG's Cabinet. The Chairman of HISPAC is invited as observer for non-Executive items.

ESA FUTURE TECHNOLOGIES COMMITTEE

The members of the Committee consist of:

- The five Working Group members who are experts in the technology issues relevant to the Working Groups.
- Three individuals from an industrial background who have a broad and innovative understanding of the potential of future technologies - Serge Flamenbaum (chair) (Astrium), Andre Perret (Neuchatel), Michael Griffin (ex-NASA, U. Alabama).
- Chair of HISPAC as ‘observer’

Two meetings and two preparatory meeting meetings have been held.

A programme of technology development of value for all the programmes and directorates of the agency.

PROJECT SHEETS

Scientific Instrumentation

Cold Atom Physics

esa

Subject / function description:

- ❑ Space Magneto Optical Trap (MoT)

TRL 2 / 3

Timescale

Long

- Life Science
- Physical Science
- Solar System
- Astronomy
- Earth Science

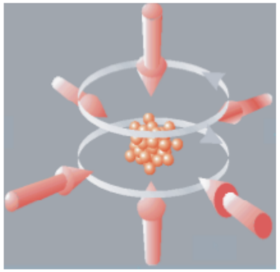
Specification:

- Goal: Cool and release into free fall a sample of an atomic species.
- On the order the of de Broglie wavelength allows increased accuracy
- Typical Temperature < 20 mK over 20 seconds
- Ambient Pressure < 10^{-9} Pascal

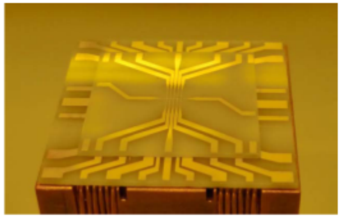
Application:

1. Atomic Interferometric Accelerometer (TRL 3)
   - Differential measurement between two atomic species at ~10^{-15} accuracy using ^{87}Rb & ^{85}Rb
2. Atomic Interferometric Gyroscope (TRL 2)
   - Measuring rotation in the order of sensitivity 10^{-12} rad/s at 1 s integration time
3. Cold Atom Optical Atomic Clock (TRL 2)
   - Atomic reference transition for clockwork stability
4. Bose Einstein Condensate Micro Laboratory (TRL 2)
   - Long free fall times to cool atoms, to characterise macroscopic behaviour of quantum gases

Magneto Optical Trap (MoT)



Atom Chip



Missions:

- ❑ Earth's Gravitational Field
- ❑ Pioneer Anomaly and Heliospheric Gravity
- ❑ Gravitational Red-shift measurements
- ❑ Frame Dragging Measurements
- ❑ Optical Atomic Clocks in Space
- ❑ Universality of free fall
- ❑ Microgravity Cold Atom Physics Laboratory

RECOMMENDATIONS (1)

Cold Atom Devices: Optical Clocks & Atomic Interferometry

The FTAP highlights the importance of the subject for future science in space for Fundamental Physics, Earth Observation, Navigation and many other areas. It recommends that an ambitious R&D programme for Optical clocks and Atomic Interferometry be implemented that combines common enabling technologies. The objective is to increase significantly the maturity and performance of the building-block technologies. Given the complexity of the devices, strong system engineering oversight is recommended. The system engineering focus should be on Optical Clocks, including time & frequency transfer.

RECOMMENDATIONS (2)

Large Ultrastable Structures

The FTAP recommends that a technology cluster roadmap on large ultrastable structures should be created. The roadmap should encompass large ultrastable deployable structures as well as large monolithic mirrors/telescope and metrology systems. The FTAP highlights the importance of the subject, enabling the creation of a new class of scientific missions for Astronomy, Earth Observation and many other areas of science and technology. It recommends that system studies and technology developments are undertaken to mature the concepts. Furthermore, it recommends increasing the technological maturity of high accuracy metrology.

RECOMMENDATIONS (3)

The Grand Challenges

Technology challenges have been identified for

- radiation protection
- ‘In-Space’ propulsion

As new ‘game-changing’ solutions are required for these challenges, it is recommended that an open announcement of opportunity be initiated in order to identify and to investigate new ideas for the challenges mentioned above.

NEXT CYCLE BEGINNING LATE 2012

Lasers

The FTAP highlights the importance of the subject which covers both High power Pulsed lasers, CW and ultrasable lasers for a large number of scientific needs .

IR-Detectors

The FTAP emphasizes the importance of the subject for a large number of scientific needs. FTAP highlights the importance of Time-resolved infrared spectroscopy. Furthermore, it emphasizes the importance of spin-in.

Formation Flying & Autonomous Rendez-vous

If achievable, Large Ultrastable Structure could become an alternative to Formation Flying for some missions. New scientific needs for Exploration/Capture, In Orbit servicing, Asteroid, Debris capture and other needs - technologies enabling autonomous rendezvous with non co-operative objects.

THE MESSAGE

- The key message is the importance of looking horizontally as well vertically at all the elements of the ESA programme.

- In the case of the present excellent ISS meeting, the role of the other Directorates in providing complementary and supporting science and technology to the ISS programme is practically and politically of the highest importance.