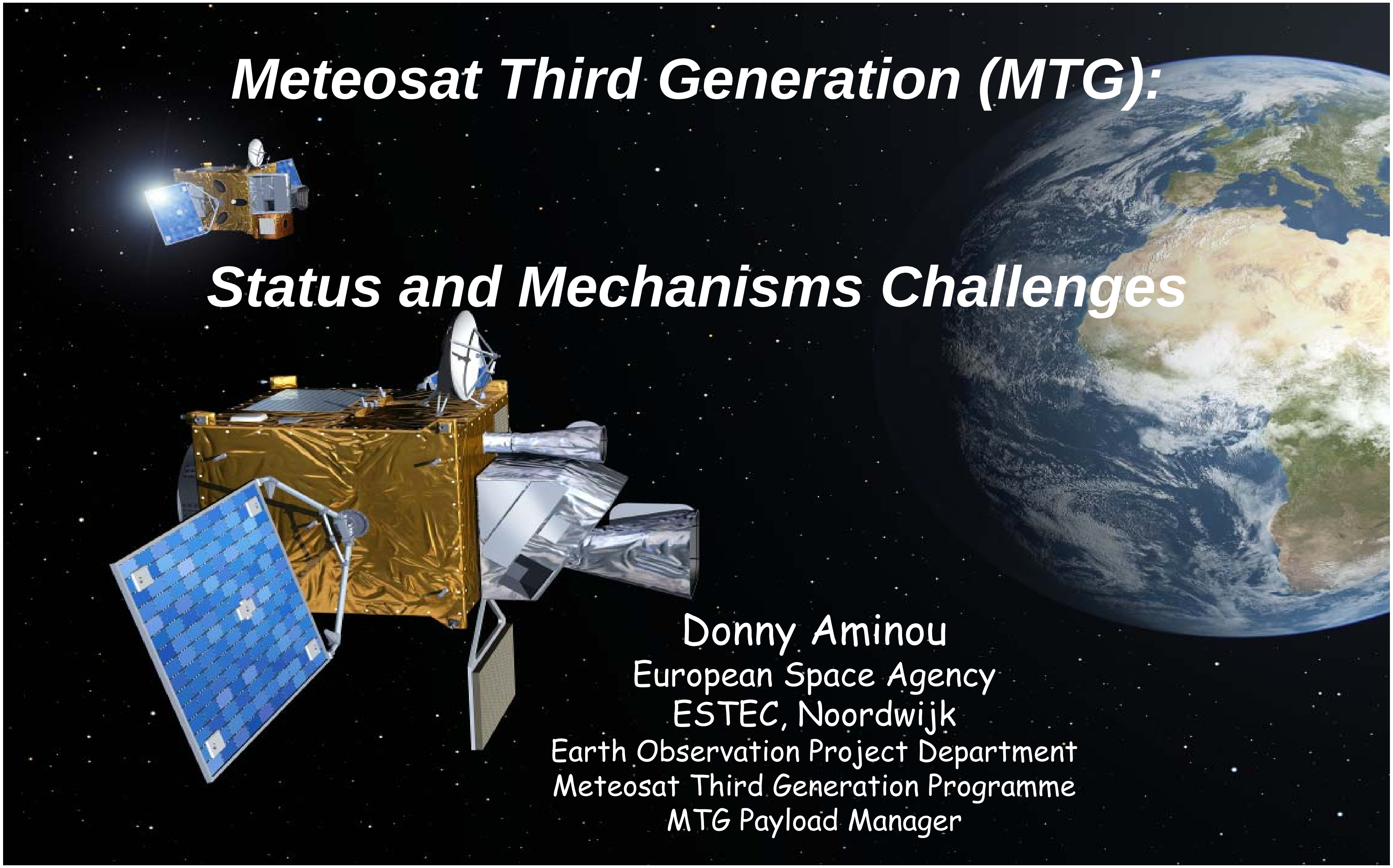

Meteosat Third Generation (MTG):

Status and Mechanisms Challenges

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Earth Observation Project Department
Meteosat Third Generation Programme
MTG Payload Manager

Topics

- *Introduction and MTG Mission and Objectives*
- *From MSG towards MTG*
- *MTG Missions: status and Planning*
- *Mechanisms on-board: challenges and needs*
- *Pre-development activities*
- *Conclusion*

MTG Programme Framework

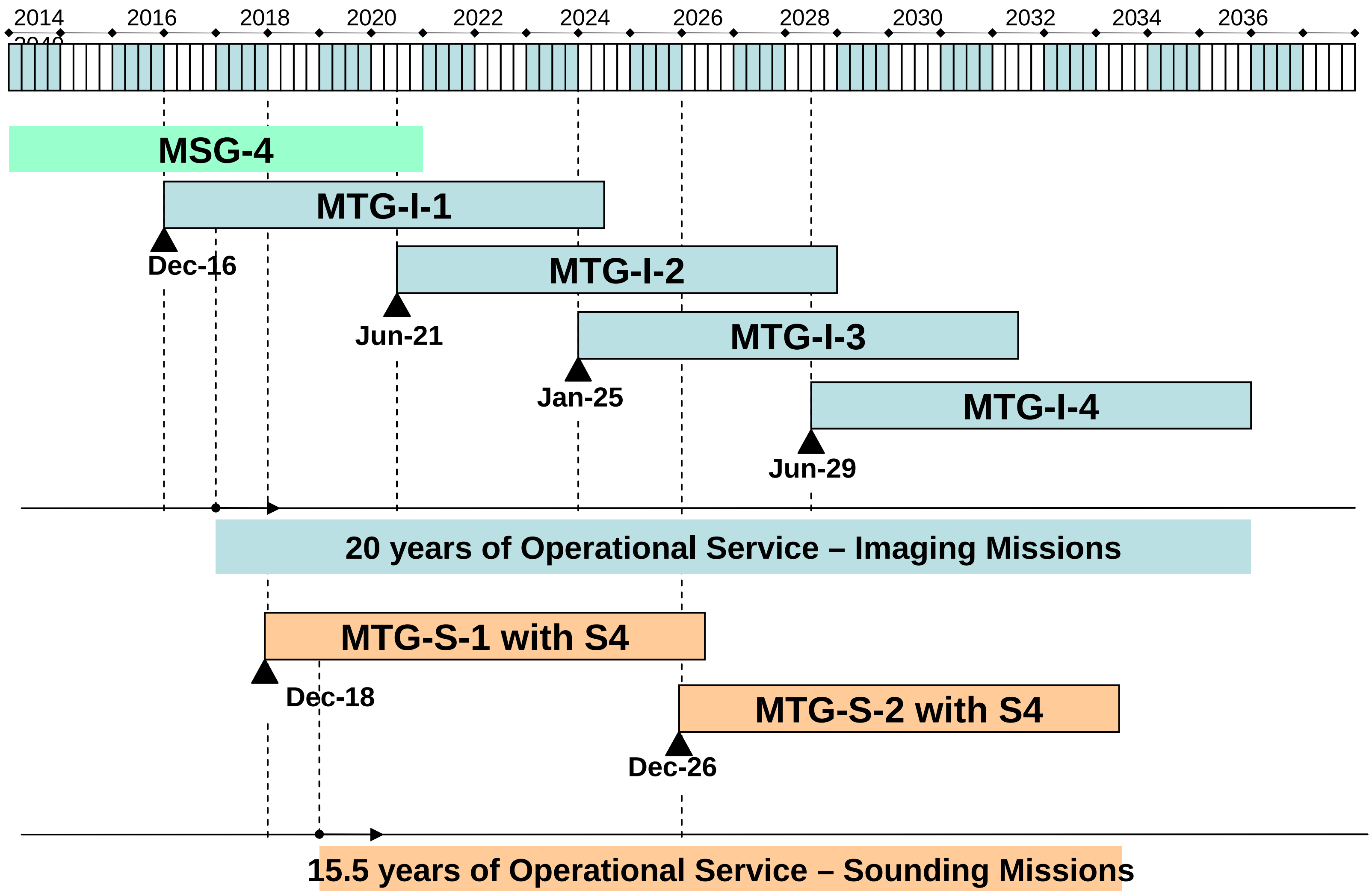
- **The overall MTG Programme is undertaken in the frame of a cooperation agreement between ESA and EUMETSAT**
  - **The <u>ESA</u> MTG Programme relates to the development and procurement of the MTG <u>Space segment</u> (plus associated support equipments)**
  - **The <u>EUMETSAT</u> MTG Programme includes;**
    - **The definition of the overall mission requirements and allocation to the space segment as appropriate**
    - **The design and development of the Ground Infrastructure required for:**
      - **Space segment monitoring, command and control**
      - **Meteorological data reception, data processing and dissemination to users**
      - **Routine operations of the MTG system for 20 years**
      - **Procurement of MTG launch vehicles**
      - **Funding of recurrent satellites and fixed contribution (<30%) to protoflight satellites for MTG-I and MTG-S <u>(all space segment procurement managed by ESA)</u>**

MTG Mission

- Objectives of MTG Mission
  - Ensure continuity of meteorological imaging data, from Geostationary Orbit, beyond the end of mission life of the existing MSG programme
  - Provide enhanced imaging performances, and new infrared sounding capabilities
  - Provide continuity and enhanced performances for long term climate monitoring
- Mission Profile (full operational system)
  - Launch Date; late 2016 for first Imaging satellite (2018 for first Sounder)
  - Overall Mission duration; 20 years
  - Space segment reliability; > 0.75 per mission chain
  - Space Segment availability (main missions); > 96% per year (throughout the overall mission life)
- Space Segment Implementation
  - 2 types of spacecraft: MTG-I (Imager) and MTG-S (Sounder)
  - Common, very high pointing stability, 3 axis stabilised platform
  - Nominal 8.5 year satellite life (following up to 10 years storage)

=> Overall space segment procurement; 4 x MTG-I & 2 x MTG-S (6 satellite procurement)

Reference MTG Satellite Deployment



Evolution on GEO Meteorology Missions

1977 2002 2017

MOP

MSG

1 observation mission:
-MVIRI: 3 channels
-**Spinning** satellite

2 observation missions:
- SEVIRI: 12 channels
- GERB
- **Spinning** satellite

5 observation missions
2 satellite types
MTG-I (Imager)
MTG-S (IR Sounder)
Common 3-axis stabilised platform

From spinning to 3-axis stabilised
- Better Radiometry
- Better Repeat Cycle
- Improved overall Performances
- Enhanced capabilities (I & S)

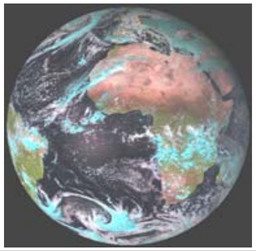
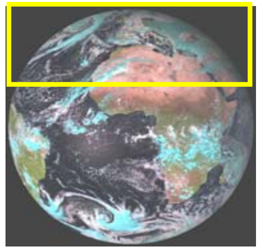
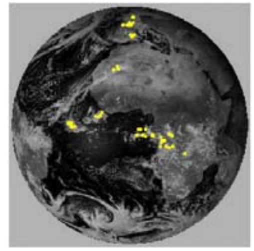
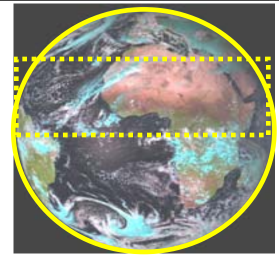
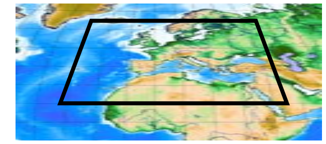
MTG Observational Missions

- Three imagery missions provided by **MTG-I** are dedicated to operational meteorology, with emphasis on nowcasting and very short term forecasting:
  - The High Resolution Fast Imagery (HRFI) mission, enhancement of the MSG HRV mission;
  - The Full Disk High Spectral resolution Imagery (FDHSI) mission, successor to the MSG SEVIRI mission;
  - The Lightning Imagery (LI) mission;

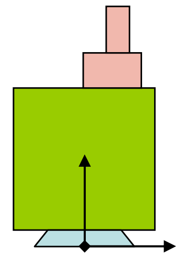
  - MTG-I also accommodates the DCS & SAR

- Two sounding missions provided by **MTG-S** focussed on operational meteorology and atmospheric chemistry;
  - An Infrared Sounding (IRS) mission focussed on operational meteorology, with potentials for atmospheric chemistry;
  - An UV/VIS/NIR sounding (UVN/S4) mission dedicated to atmospheric chemistry & Air Quality, in combination with IRS.

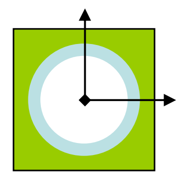
MTG Observational Missions' Coverage

				
FDHSI / FDSS BRC = 10 min.	HRFI / RSS BRC = 2.5 min.	Lightning Detection Continuous Bkg = 60 sec.	IR Sounding with 0.625 cm-1 BRC = 60 min. RSS = 15 min.	UV-VIS-NIR BRC = 60/30 min. 30°W - 45°E [@40°N] & 30°N - 65°N, FOV of 5°NS x 55°EW + Sahara Vicarious Cal.
Solar channels: SSD=1 km IR channels: SSD=2 km	Solar channels: SSD=0.5 km IR channels: SSD=1 km	Goal SSD=5 km at SSP Threshold 10 km at 45°N	Spectral Bands: 1600-2175 cm^{-1} 700 - 1210 cm^{-1} SSD = 4 km	Spectral Bands: UV: 305 - 400 nm VIS: 400 - 500 nm NIR: 750 - 775 nm SSD = 8 km
SNR >20 in VIS NEdT=0.1 – 0.2 K All channels 0.5 – 1K for FA 3.8 and 8.7 μm	SNR = 12 in VIS 0.2 K @ 3.8 and 10.5 μm	DE = 90% at 45°N DE = 70% elsewhere day/night	See next slide for NEdT template update	SNR ~ 100 - 2500

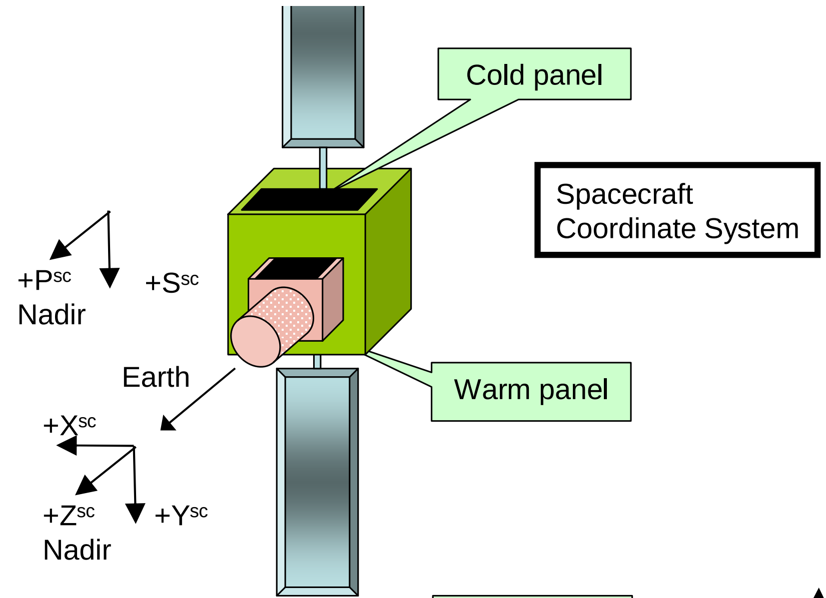
MTG Missions Spatial Coverage and Temporal Rate

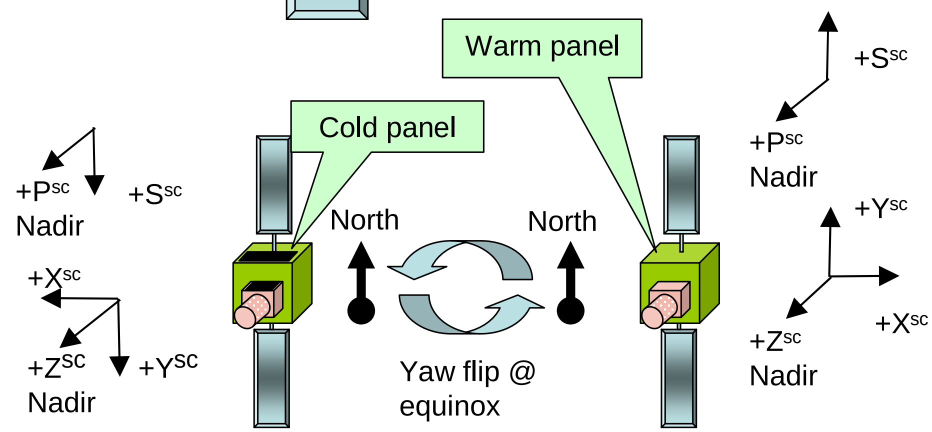


"One of the SC axis shall be perpendicular to the Launcher I/F plane."



"The two other axes shall be within the Launcher I/F plane, (one) perpendicular to a platform panel."



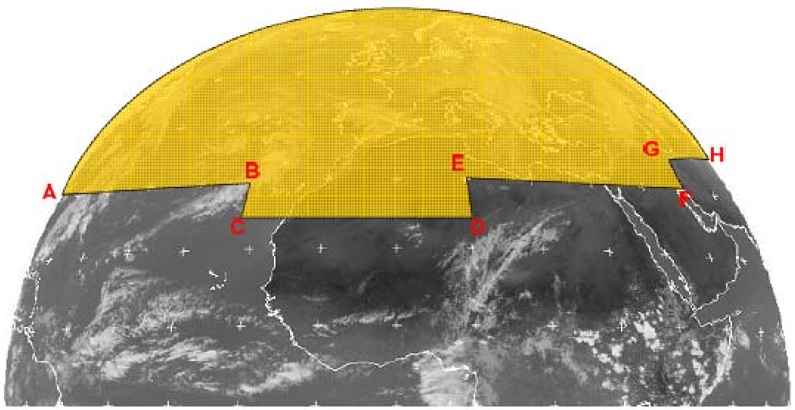


Northern Hemisphere Winter   Northern Hemisphere Summer

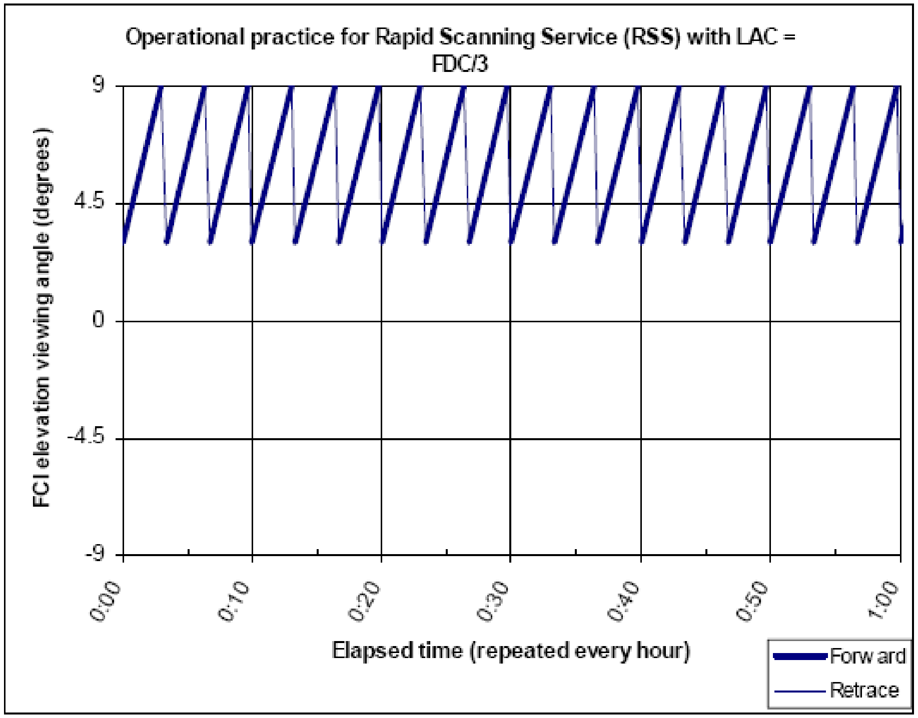
MTG platform

- Common platform design for MTG-I and MTG-S derived from telecom (with enhanced pointing & stability)
  - ➔ Eurostar (Astrium)
  - ➔ Spacebus (Thales Alenia Space)
  - ➔ Small GEO (OHB)
- Compatibility with Soyuz in Kourou (maximum launch mass ~ 3000 kg)

MTG Satellite Symmetrical Dual Array Configuration

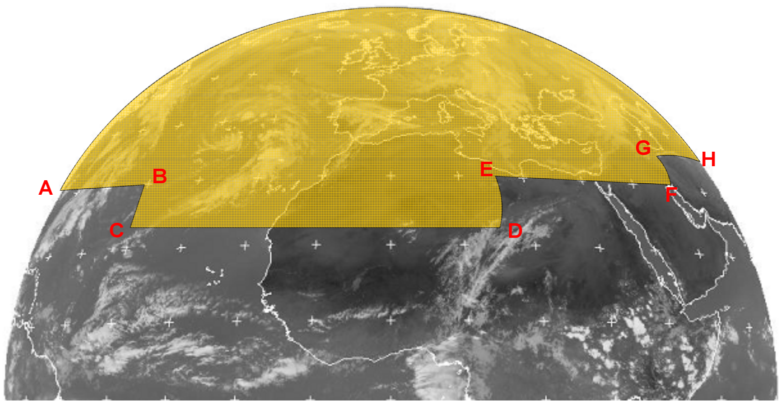


AB	30°N
BC	22°W
CD	25°N
DE	10°E
EF	30°N
FG	50°E
GH	35°N

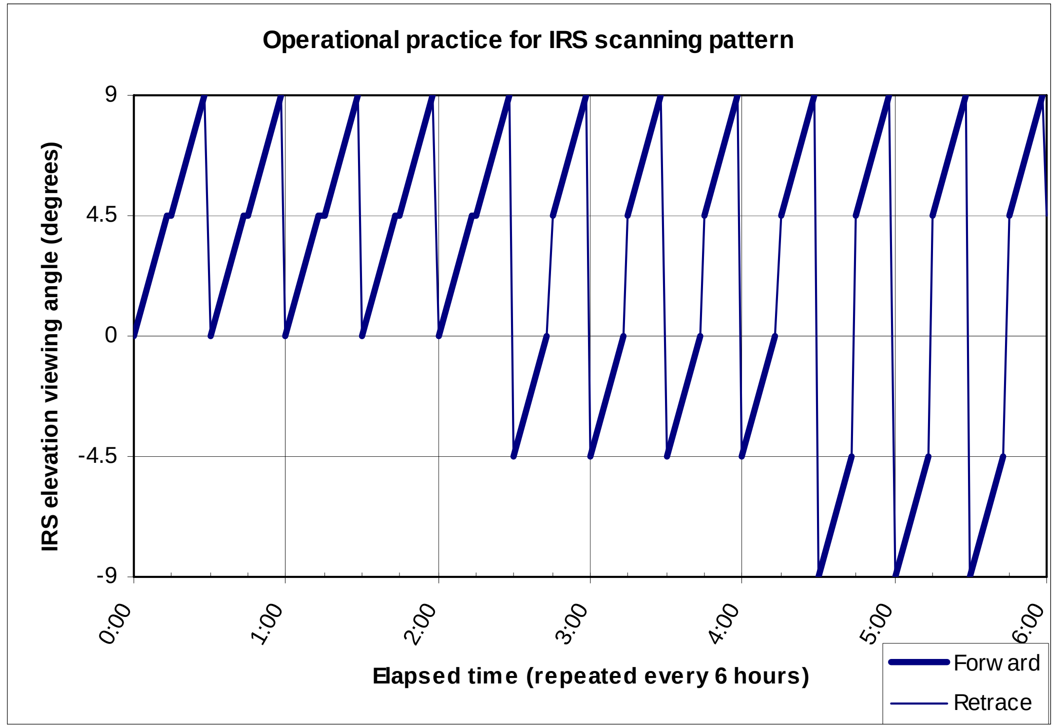


RSS for MTG-I/FCI covering down to 25°N in 2.5 minutes, covering Tenerife and some Southern Atlantic.

To meet those imaging requirements, a highly accurate san mechanism is mandatory



AB	30°N
BC	40°W
CD	22°N
DE	15°E
EF	30°N
FG	50°E
GH	35°N



Rapid Scanning Services for MTG-S/IRS covering down to 22°N in 15 minutes (goal) with 20 min (threshold), covering Tenerife and some Southern Atlantic

To meet those Sounding/imaging requirements, an accurate san mechanism is mandatory

Image Navigation and Registration

- Accurate Image Navigation and Registration (INR) is key to success for MTG mission
- The 3-axis stabilised satellite configuration leads to:
  - Acquisition of successive swaths
  - Geometric deformation caused by the 2-axis gimbal mirror will differ from a swath to the following
  - Overlapping between successive swaths (MTF shaping, provision for attitude errors, swath to swath error, sampling error…)
  - Super fine instrument and platform models including thermo-elastic aspects, micro-vibrations, scanning laws, etc…
- Assessment of geometric requirements (i.e. correlation with landmark database) for image correction is performed by means of rectification at level 1c, using the various "high" accuracy observables on-board: Star trackers, Gyros, 4-5 RW_AOCS and from the GS: ranging, landmarks, high finesse modelling of Thermo-elastic deformations, accurate scanning law knowledge, etc...

MTG Mechanisms Critical Technologies

Critical Items	Pre-Dev. Contract Awarded to	MTG related instruments	Status
Large Pulse Tube Cooler (LPTC)	Air Liquide (F) No flight heritage in Europe	FCI and IRS Lifetime Qualification at components' level envisaged	Kicked-off Nov. '07 2 EM's delivered Endurance test to start September '09
High Power Stirling Coolers (HPSC)	Astrium (UK) Heritage from 50-80K coolers with long flight experience (ERS, ENVISAT, etc…)	FCI and IRS If HPSC is used, some qualification by similarity and/or at components' level maybe necessary	Kicked-of Nov. '07 CDR performed 16 Sept. '09 Manufacturing BB on-going
Scan Mechanism Breadboarding and Related Components	• Astrium GmbH (D) as prime + Astrium SAS (F) + Sener (E) • TAS (F) + Ruag (CH)	FCI, IRS and UVN Scan Mechanism proof of concept and performance achievements for INR	Kicked-off early 2009, Passed Requirements Review in June/July '09
Voice Coil Motor	TRP to CEDRAT (F)	FCI, IRS, UVN	TRP finalised, improvement in bread boarding of scan mech.
Encoder	Within scan mechanism	FCI, IRS, UVN	Improvement in phase GSTP or B2, C/D activity
Flexible hinges	Within scan mechanism	FCI, IRS, UVN	Improvement in phase B2, C/D activity
Interferometer	None	IRS	B2, C/D activity

- Scan Mechanisms (driven by the FCI scanning requirements, lifetime and accuracy): Bread boarding activities of critical technologies in preparation for both potential Prime contractors [Astrium (G) and TAS (F)].
- Scan mechanism breadboarding to reflect Image Navigation and Registration (INR) performance needs.
- Fast scanning axis in East/West and W/E direction swathing the Earth;
- Slow scanning axis in South/North;
- Delivery of quasi-representative scanning law and its perturbations towards the satellite/instrument INR for compensation strategies on-board or on-ground;
- Early risk mitigations (Components: actuators, encoders, hinges and ball bearings as appropriate including qualification and feasibility aspects).

Critical Technologies Identified

- In view of the MTG challenging accuracy and pointing performance requirements, and following the pre-study Phase performed by industry, the technology status concerning the following mechanical components has been identified as critical:
    - position sensors (optical encoder)
    - scan actuator (Voice Coil Motor)
    - flexural elements (pivots)
    - Ball bearings wrt lifetime and cleanliness (lubrication)

- Trade-off have shown VCM as being the best actuator for performance and robustness
- Actuators based on voice-coil principle (loudspeakers), torque proportional to current, simple drive electronics, low electrical time constant
- Magnetic design for high efficiency is important
- Configuration as linear motors in push-pull (VCM), or rotary actuators (Limited Angle Torquers LAT)
- Heritage on several space missions
- Simple actuator principle
- Risk on MTG is mainly coming from unexperienced EU suppliers rather than from real technology issues (ETEL nor more delivers space applicable VCM).

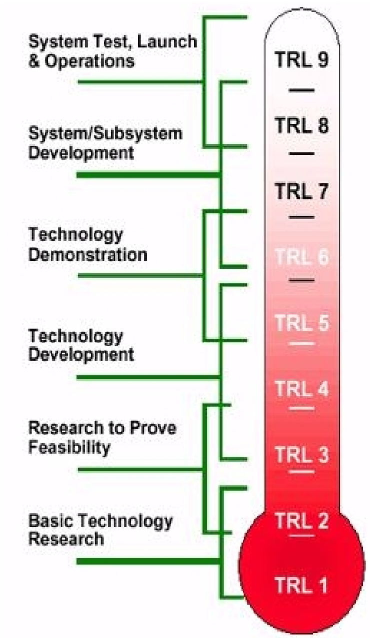
Challenges / Feasibility issues / Alternatives

- **Main challenges:**
  - to avoid high frequency variations in the motor torque constant
  - to provide a low electrical time constant for control loop efficiency
  - optimize mass/efficiency and power consumption

- **Feasibility:**
  - readiness of non-heritage suppliers ITAR free (CEDRAT, Ruag)

- Alternatives:
  - US models (equivalent technologies) with ITAR involved
  - Brushless DC motors with low electrical time constant

TRL 3 - 5



MTG application & heritage

- **MTG main requirement is on speed stability of scan mechanism:** repeated errors will be calibrated out for FCI / IRS / UVN scan mechanisms
- **Flight heritage from Pleiades, and baselined in its heritage version for S3 and Alphasat.**
- **BUT:**
  - **Heritage items use level-2 active elements (mil-standard only) and**
  - **Obsolete parts by MTG/S4 need time (signal conditioning ASIC)**
  - **And existing Phototransistor technology is lifetime critical (accuracy degrades due to radiation & temperature)**
  - **Possibility to use photodiode is being investigated?**
- **ESA & CNES pre-development activities in preparation** with focus on new components and radiation
- **Potential Source Suppliers in EU, USA and Japan: Several**

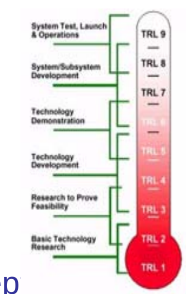
Optical Encoder Challenges

Challenges / Feasibility issues / Alternatives

- **Main challenges:**
  - to achieve the required speed stability measurement
  - to select the correct technology (heritage photoransistor with drawbacks vs. new photodiode with risk)
  - ASICs for signal processing enhancement

- **Feasibility:**
  - Cocooning possible for transistor technology ?
  - Diodes have no new disadvantages ?
  - Securing of funding as identified in the ESA harmonisation roadmap (TRP, GSTP)

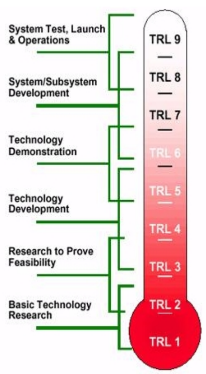
- Alternatives:
  - Optical encoder from UK, USA and Japan (equivalent technologies, tbc)
  - RVDT principle from USA, mass & EEE complexity penalty



TRL 3 - 5

MTG application & history

- **Flex-pivots may be used on MTG**
- **Heritage for custom made pivots is based on ODL mechanism (with Ruag Space for Darwin which has been stopped), or HAFHA pivots (developed under ESA GSTP contract by Sener)**
- **Custom made pivots are manufactured from monolithic material (stainless steel or titanium), analytical tools (FEM based) exist to predict performances**
- **Alternative technology => using pivots from catalogue US source with ITAR constraints and some technical drawbacks wrt performance optimisation.**



TRL 3 - 5

Challenges / Feasibility issues / Alternatives

- **Main challenges:**
  - go ahead with stiffness and functional optimized pivots (custom made)
  - avoid hammering in general or avoid damage due to hammering during vibration (if no LLD); avoid further overdesign of motor actuator
  - provide sufficient stiffness to allow for ground testing in any direction

- **Feasibility:**
  - has been already demonstrated, refer to HAFHA for Sener and ODL for Ruag.
  - further confidence will be established by the on-going breadboard activities.

- Alternatives:
  - using off-the shelf pivots from the catalogue;
  - suppliers identified from US market (e.g. Riverhawk) with ITAR constraints

MTG application & history

- **Ball bearings could be used in MTG mechanism design**
- **Heritage can be claimed from many space applications built and flown; however load profile and lifetime requirements always different, consequently leading to a different behaviour of the bearings.**
- **A good example of Heritage can be claimed from SEVIRI extended life tests (about 1 million cycles);**
  however test results revealed wear of MoS2.
  Therefore, early confidence tests foreseen to assess adequacy (wrt lifetime and torque) of Fomblin Z60 and MoS2 as potential lubrication solutions for MTG
- **Other issue raised also wrt contamination cleanliness.**
  However, evaporation rate of Fomblin Z60 oil is extremely low (confirmed by tests at ESTL and ESA)
- **Note that MoS2 coating will be applied by well proven procedures (qualified process) to the bearing components.**

Challenges / Feasibility issues / Alternatives

- **Main challenges:**
  - to meet lifetime requirement in line with specified success criteria
  - to confirm by life test the expected low contamination levels

- **Feasibility:**
  - because of the high contact pressure within the bearings (due to high preload in consequence of the cantilevered design w/o LLD) there is a risk that both lubricant candidates will not provide successful results.

- Alternatives:
  - use of lead lubricated bearings (ion plated Lead process for balls and races with lead-bronze cage); however higher resistive torques expected
  - others?

TRL 3 - 5

MTG needs:
~ 2 W heat lift, < 150 W *
55 K Cooler:
Led to 2 pre-developments:
*LPTC from: Air Liquide (F)

High Performance Stirling Cooler (AST UK)

Existing Technology includes: **
- Astrium UK 50-80 K Stirling Coolers**
- Actual development of high power Stirling based on the 50-80 K heritage

- American sources (ITAR): NGHT HEC Coolers, and others

Cryocoolers Qualification Aspects

- Lifetime qualification: Cooler mechanism required to get power into the gas
  ➔ to optimise efficiency, cooler is operating near resonance of mechanical/gas system (40-50Hz) ➔ 10^{10} Cycles needed for MTG.

  - Additional cycling in the system due to the pressure wave generated by the mechanism (several bar) operating the cooler outside the normal frequency range will result in different stresses inside the cooler and different pressure waves
    Accelerated life tests on system level are not feasible**;**

  - Alternative solution: life test at components' level.

Conclusion (1)

- ☐ MTG is a very challenging mission with many mechanical components involved in achieving successful mission
- ☐ MTG critical mechanisms and components have been pointed out early in phase A: scan mechanisms and components, cryocoolers, etc…
- ☐ Pre-Development activities have been initiated for risk reductions
- ☐ - LPTC has been developed by Air Liquide (F), EM is being tested for endurance starting end of September 2009.

  - High Power Stirling Coolers are at CDR level for the compressor
  - Scan Mechanism breadboarding activities have started by both primes
  - VCM EM is being built by CEDRAT (F)
  - Flex pivots, ball bearings are being tested and analysed

➔ Satellites INR is fully being developed by the competing Primes

Conclusion (2)

The MTG-I schedule remains challenging but compatible with the end 2016 readiness for launch (consistent with MSG continuity)

MTG-S development is considered compatible for launch by end 2018

MTG space segment ITT for phase B2, C/D has been released with target Kick-Off for Phase B2 early 2010

We need you!
We need your expertise!
We need your mechanisms!
To win against the challenges ahead.

Thank you for your attention!