CGMS-51-WGI-WP-05
5 April 2023

Prepared by: EUMETSAT
Agenda Item 6.1
Discussed at WG-I

Subject	**Report from the CGMS WGI Task Group on the Coordination of LEO Orbits (incl. latest ToR, status on current & proposed/planned activities)**
In response to CGMS action/recommendation	WGI/A50.09 (linked to Paper CGMS-51-WGI-WP-06), WGI/A50.10 (linked to Paper CGMS-51-CGMS-WP-02)
HLPP reference	
Executive Summary	In Paper CGMS-51-WGI-WP-06 (Combined Report from the CGMS WGI Task Groups on Direct Broadcast Systems and LEO Coordination of Orbits (LCOO TG), it is proposed to consolidate the existing TGs into a new single Low Latency Data Access Task Group (LLDA TG) This Paper provides links to the work performed so far by the LEO Coordination of Orbits Task Group, as well as the final Terms of Reference, such that activities may be taken into account in the new LLDA TG. Reference is also made through this consolidated TG approach to the BPs formulated in the LCOO TG, while a separate Paper CGMS-51-CGMS-WP-02 formally closes the action.
Action/Recommendation proposed	Refer to actions proposed in CGMS-51-WGI-WP-06.

1 INTRODUCTION

In Paper CGMS-51-WGI-WP-06 (Combined Report from the CGMS WGI Task Groups on Direct Broadcast Systems and LEO Coordination of Orbits (LCOO TG), it is proposed to consolidate the existing TGs into a new single Low Latency Data Access Task Group (LLDA TG)

This Paper provides links to the work performed so far by the LEO Coordination of Orbits Task Group, as well as the final Terms of Reference, such that activities may be taken into account in the new LLDA TG.

Reference is also made through this consolidated TG approach to the BPs formulated in the LCOO TG, while a separate Paper CGMS-51-CGMS-WP-02 formally closes the action.

2 SUMMARY OF WORK PERFORMED

Initial discussions on the potential advantages of LEO orbit coordination arose in the Direct Broadcast papers from CGMS-44 (see table below)

CGMS-44, 45, 46 WGI	CGMS agency best practices in support to local and regional processing of LEO direct broadcast data		
CGMS Agency Best Practices in support to Local and Regional Processing of LEO Direct Broadcast data (J. Gonzales Picazo)	CGMS to consider the advantages of orbital phasing between satellites as a measure for reducing pass scheduling conflicts and maximising the amount of instrument observation collected. *No formal action raised in CGMS-44 / 45.*	CGMS-44-EUMETSAT-WP-07 CGMS-45-EUMETSAT-WP-32	24/02/2017 30/05/2017
Update of CGMS agency best practices in support to local and regional processing of LEO direct broadcast data. (S. Burns)	WGI/AI 46.02: Present the current operational orbit maintenance strategy, input to discussion of orbital phasing between satellites as measure for reducing pass scheduling conflicts and maximising the amount of instrument observation collected, with view to producing future best practice.	CGMS-46-CGMS-WP-15	18/05/2018

This eventually led to a specific action in CGMS-46 leading to progressive analysis from CGMS-47 onwards

Formation of dedicated Task Group was initiated following CGMS-48.

CGMS-47, 48, 49 WGI	System technical aspects (sharing/rationalisation of orbits) and operational aspects on the implementation of contingency plans		
Coordination of LEO orbits – An analysis (A. Monham)	Responded to A46.02. Presented analysis of drivers / constraints in coordinating LEO satellite orbits & potential gains in terms of improved mission return and ground resource usage efficiency. A47.10 raised to produce simulation algorithm A47.11 raised to produce Best Practice	CGMS-47-EUMETSAT-WP-09 PPT	19/05/2019
Coordination of LEO orbits – Outcome of simulations (A. Monham)	WGI/A48.08: The Task Group to check work performed for: • applicability to operational and planned missions • assess formulation of a BP on coordination of LEO orbits • determine further work required on the simulation tool	CGMS-48-EUMETSAT-WP-04 PPT	25/05/2020
Best Practice for the Coordination of LEO Orbits – Progress and Next Steps (A. Monham)	Closed A48.08. New actions: WGI/A49.05: Issue Draft BP on Coordination of Data Acquisition for LEO Satellite Systems (with uncoordinated / variable orbital phasing) WGI/A49.06: Perform a broad SWOT analysis for maximising the return / minimising the cost taking into account new mission and reference mission concepts and associated technologies, highlighting the potential for inter-Agency cooperation	CGMS-49-EUMETSAT-WP-05 PPT	09/04/2021

CGMS-50 WGI	Coordination of LEO Orbits		
Report from the CGMS WGI Task Group on the Coordination of LEO Orbits (A. Monham)	Closed WGI/A49.06 with new action: WGI/A50.09: Work with DB group to provide consolidated SWOT analysis, including usage of emerging technologies for Low Latency Data Access from LEO satellites for both global and regional data	CGMS-50-EUMETSAT-WP-01 PPT	22/04/2022
Proposed Best Practices for the Coordination of Data Acquisition for Low Earth Orbit Satellite Systems (J. McNitt)	Closed WGI/A49.05: 3 BPs proposed for coordination of satellite systems with variable orbital phasing. WGI/A50.10: Review overlap with DB BPs (CGMS/DOC/18/1008274)	CGMS-50-NOAA-WP-05 PPT	20/04/2022

The consolidated Report of the DB TG and LEO Coordination of Orbits TG is provided under CGMS-51 WGI Agenda Point 4.1. CGMS-51-WGI-WP-06

This proposes that TG activities be merge into a single Low Latency Data Access TG covering both global and regional mission objectives.

Existing Best Practices will be consolidated under this new TG: CGMS-51-WGI-WP-06 , CGMS-51-CGMS-WP-02

Refer to CGMS-51-WGI-WP-06 for formal recommendations and proposed actions.

ANNEX 1: TERMS OF REFERENCE (FINAL VERSION)

CGMS WG1

TASK GROUP ON BEST PRACTICES FOR THE COORDINATION OF LEO ORBITS

(VERSION 2, UPDATED PRIOR TO CGMS-50)

TERMS OF REFERENCE

1. BACKGROUND AND GOAL OF TASK GROUP

The topic of Orbital Phasing was first introduced in the Direct Broadcast Best Practices at CGMS-44 in 2016 and has been presented at all subsequent meetings. The expected benefits have been identified as follows:

- Reducing pass scheduling conflicts
- Maximising the amount of instrument observation collected
- Reducing risk of radio frequency interference
- Fixed temporal separation between instrument observation
- Reduced risk of satellite proximity

In-orbit phasing within same orbital plane / operating agency already occurs, as presented to CGMS-46[1], demonstrating the ease and benefits of this coordination.
Further to this, a preliminary analysis of the drivers and constraints in coordinating LEO satellite orbits and the potential gains in terms of improved mission return and ground resource usage efficiency was presented at CGMS-47[2].
Building on these previous inputs, a prototype simulation algorithm and results illustrating coordination possibilities for in-orbit separation between different satellites and satellite constellations / operating was presented to CGMS-48[3]. CGMS WG1 decided to form a dedicated Task Group with the ultimate goal of establishing a "Best Practice for the Coordination of LEO Orbits" while assessing the prototype simulation tool's applicability to operational and planned missions and determining whether further work is required on that tool.

2. POTENTIAL BENEFITS FROM COORDINATION OF LEO ORBITS

The Working papers identified in the Introduction have highlighted the possible benefits for CGMS members and their user communities in coordinating the LEO orbits

[1] CGMS-46-EUM-WP-15: Update of CGMS agency best practices in support to local and regional processing of LEO direct broadcast data.
[2] CGMS-47-EUM-WP-09: Coordination of LEO orbits – An analysis
[3] CGMS-48-EUM-WP-04: Coordination of LEO orbits – Outcome of simulations

to align the repeat cycles (altitude), irrespective of which orbital plane Mean Local Solar Time is preferred. These benefits can be further enhanced through coordinating the respective missions' MLST values, both from the perspective of further optimising the satellite capacity of each orbital plane and from the user data perspective.
The benefits are summarised as follows:

- Reduction of ground station resources required and therefore long-term operational costs, by preventing conflicting passes.
    - *This applies to polar station sites used for global mission dumps as well as the worldwide Direct Broadcast station networks.*
- Maximising the amount of data collected, avoiding loss of "lower priority" data due to pass visibility or RFI conflicts.
    - *Note that such data may well be classified as lower priority from the perspective of the ground station owner who naturally prefers to acquire their own satellites, rather than lose data in favour of another operator's satellite, whereas its acquisition remains valuable to the user community.*
- The fixed conflict pattern over local stations across the globe allows optimisation of data collection from all supported satellites on coordinated orbits.
    - *Over the combined repeat cycle, any conflict events are repeated and predictable.*
- Elimination of RFI events from concurrent passes using separate antenna.
    - *Where maximum utilisation of coordinated orbital planes is required (especially relevant where three or more orbital planes are coordinated), then multiple ground station antenna on a given site can be used to resolve pass visibility conflicts, but the fixed separation of passes can be designed to ensure these will never suffer radio frequency interference. This will again maximise user data.*
- Avoiding need to remove older generation satellites from an orbital plane.
    - *Typically satellite operational lifetimes are substantially longer than their required, design lifetime, leading to overlaps of new satellite programmes with the previous generation. Through coordination of orbital planes, the operational cost of these satellites can be reduced since they may continue to share ground resources, thereby potentially allowing lifetime extensions to become more affordable.*
- Fixed temporal separation of mission data acquisition can help reduce communications costs.
    - *It averages out the data collection profile over time, avoiding driving requirements from peak load worst cases.*
- This temporal separation is also likely to be more efficient and effective for end-users' assimilation processes.
    - *Peak loads are also avoided and the consistency of separated temporal acquisitions should benefit forecasting quality.*

Although the risk of satellite proximity was originally identified as a potential benefit of orbit coordination, it is currently believed that satellites operating with fixed phase coordination (same altitude) and those operating with dynamic, uncoordinated phasing (different altitudes) generally pose no threat to each other (provided the altitude difference is greater than a few kilometres. Coordination required between active satellites in the sense of satellite conjunction management / collision avoidance is not considered in scope of this Task Group and is to be handled by a separate Task Group. Satellite proximity is therefore not being considered as a specific driver for the assessment.

Clearly, effort would be required to analyse the coordination possibilities and agreements on shared ground facilities development and maintenance will be more complex from a programme development management perspective than simply procuring dedicated, independent resources for each programme. Given the foreseen duration of supported missions and the expected lifetime of ground facilities (which may span more than one mission), it would be expected that this effort could provide significant programme cost savings over the operational lifetimes of the mission, along with the above mentioned user benefits in terms of increased data return.

3. TASK GROUP FOCUS

There are two main areas of focus for the Task Group:

- Maximising efficiency / effectiveness of ground station resources in support of orbits with uncoordinated / variable phasing (i.e. those operating on different repeat cycles / altitudes).
- Assessing development and operational trade-offs for phase coordination of satellite systems (i.e. operating on same repeat cycle / altitude).

The following areas will not be a focus of the Task Group

- Close proximity positioning for combined mission observations (e.g. inter-calibration / simultaneous observation objectives). *Note that while analysing the drivers/constraints to achieve close proximity operations is out of scope, coordinating other satellite systems with formation flying satellites can be considered within the scope of the Task Group. Interfaces to the A-Train Constellation Working Group will be established to ensure constraints are taken into account.*
- Collision Avoidance, Conjunction Management between active satellites. *This is addressed through a separate task group.*

Tasks concerning existing and planned satellite systems with uncoordinated / variable orbit phasing

- Define a Best Practice for maximising the return / minimising the cost using ground segment coordination. This is expected to include, but not limited to:
    - Preparation of multi-mission ground stations
    - Sizing of data communication networks.
    - Definition of operational Concepts for satellite downlink efficiency (flexible dump start/stop, etc.)
    - Prioritisation schemes for satellite data acquisition
    - Analysis and operational planning related to avoidance of Radio Frequency Interference
    - Ground station and network redundancy analysis for multi-mission support.

Tasks to assess the coordination potential for future satellite systems’ orbital phasing

- Define a Best Practice for maximising the return / minimising the cost using both coordinated orbital phasing and ground segment coordination. This is expected to include, but not limited to:
    a. Consideration of programmatic factors:
        i. Cost – benefit analyses: what kind of savings can be made on ground resources per year? What level of extra mission data might be obtainable (considering dumps as well as local downlinks)
        ii. Planning development of shared resources across agencies
        iii. Management of dependencies: achieving self-sufficiency but adding value from shared resources from coordination scheme
        iv. Models for allocation or sharing of costs on joint agency-owned resources (use of external service suppliers for ground resources would be a simpler approach for costing (based on usage per mission/agency).
    b. Consideration of operational factors:
        i. Level of operational coordination acceptable (e.g. fixed scheme with no coordination, or pre-defined repeat cycle based operational agreements, or frequent scheduling exchanges on dumps, manoeuvres etc.).
        ii. Operational Interface Agreement documentation, coordination and change mechanisms.

- Assess role of simulation tool in formulating the Best Practice. This is expected to include, but not limited to:
    - Use of the EUMETSAT developed prototype in support of the above Best Practice related analyses.
    - Asses the prototype simulation tool's applicability to operational and planned missions
    - determine whether further work is required on the simulations tool.

4. DELIVERABLES:

The main deliverable is a CGMS Best Practice for the Coordination of LEO Orbits, structured in two main sections according to the focus areas defined above:

i) Best Practice for the Coordination of Data Acquisition for LEO Satellite Systems with uncoordinated / variable orbital phasing, for maximising the return / minimising the cost using ground segment coordination.

ii) An analysis of the potential benefits and considerations to be made in the development and operations of LEO Satellite Systems with coordinated orbital phasing for maximising the return / minimising the cost using both coordinated orbital phasing and ground segment coordination.

5. SCHEDULE

Version 1 of the Best Practice will prioritise the first section defined above (Coordination of Data Acquisition for LEO Satellite Systems with uncoordinated / variable orbital phasing) and should be in a final draft for by October 2021.
Drafting of the second section can be completed as far as possible in this timeframe.
Version 2 of the Best Practice shall complete the second section on the assessment of LEO orbital phasing coordination and should be in a final draft for input to the CGMS-50 meeting. Due date March 2022.

Detailed planning on intermediate drafts and allocation of tasks is to be made in the dedicated Task Group meetings.

6. PARTICIPATION

All CGMS Member Agencies are invited and encouraged to propose participants to this Task Group. The list below represents nominated individuals so far. Other participants not listed below are also welcome to join Task Group meetings.

CMA:

- Lei Yang (Deputy Director, Meteorological Satellite Engineering R & D Division)
- Dr. Lizi Xie
- Shuze Jia

EUMETSAT:

- Andrew Monham (LEO Spacecraft Operations Manager) Task Group Leader
- Pier Luigi Righetti (Flight Dynamics Manager)
- Jose Maria de De Juana Gamo(Flight Dynamics LEO Lead Engineer)

JAXA:

- Toshi Kurino

KMA:

- Sung-Rae Chung (Senior Researcher, Satellite Operations Division)

NASA- GSFC

- James Butler
- Gabriel McDonald
- Jack Lauderdale (System Engineer, JPSS)

NOAA

- Justin Gronert (OSPO JPSS Mission Operations Manager)
- Christopher Anders(*Acting* JPSS Program Chief System Engineer)
- Becky Mesarch (JPSS Program System Engineering)
- Kevin Schrab
- Satya Kalluri
- Changyong Cao
- Mark Turner
- Beau Backus
- James McNitt (Direct Readout Program Manager)
- Gregory Mandt (JPSS)