Space Weather Roundtable, June 1-2, 2023

GDC Relevance to NOAA

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National Environmental Satellite, Data, and Information Service

NOAA use of GDC observations

- Atmospheric drag on spacecraft in LEO from measurements by GDC – note the Office of Space Commerce within NOAA is charged with providing basic SSA data and STM services to commercial space operators especially due to the proliferation of commercial constellations.
- Radio propagation for communications, navigations, and surveillance – note radio occultation from GDC’s polar orbits complement COSMIC-2 low latitude orbits - assessing impacts to GPS system among others.
- Assessment of geomagnetic disturbances in LEO will enable space weather predictions of ground level technological events, e.g. GICs in the power grid among others.
- Assessing the radiation environment of LEO impacting spacecraft systems and human exposure.
- GDC has a real-time beacon and is working with both research and operations to optimize transmission content and latency.

GDC observations vs NOAA requirements

- GDC re-engineered the downlink from a daily scientific download to a space based near real-time broadcast via a commercial receiving network for partial observations needed for NOAA’s space weather notification system.
- GDC has a real-time beacon and is working with both research and operations to optimize transmission content and latency; management has appointed a Deputy Project Scientist to specifically address space weather issues and GDC capabilities.
- NOAA requirements from missions like COSMIC-2 were cross referenced to GDC capabilities such as observations of magnetic field, neutral wind characteristics, I-T characteristics, total electron content and energetic particle populations and precipitation.
- From the IRB (Sept. 2022): GDC observations of I-T conditions will lead to “improvements in I-T models that are foundational to Space Situational Awareness and Space Weather prediction.

GDC Capabilities vs NOAA requirements

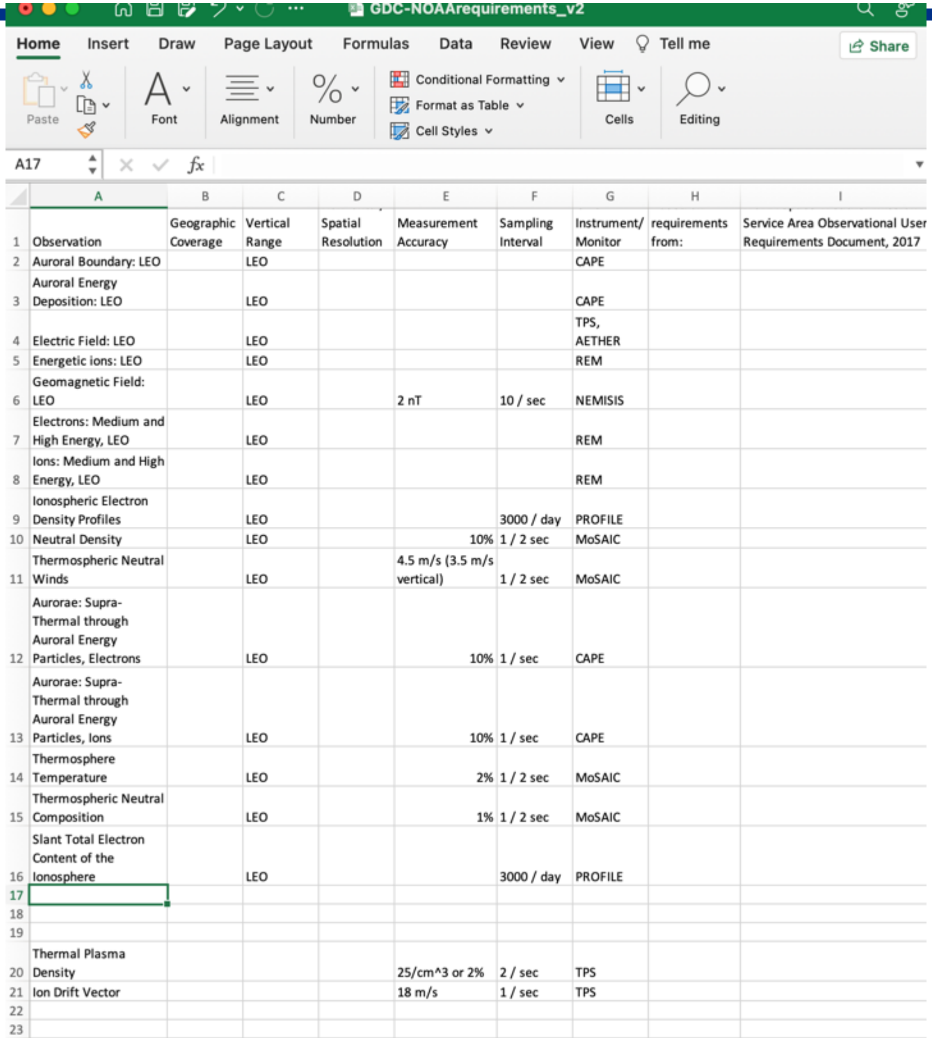
GDC Instrument Suite	NOAA Observation Requirements
Magnetometer (NEMESIS)	Magnetic Fields
Radio Occultation (PROFILE)	TEC, NmF2, hmF2
Atmosphere and Ionosphere (MoSAIC)	Neutral Winds, I-T characteristics
Auroral Precipitation Experiment (CAPE)	Auroral Precipitation – particles, energy deposition, and auroral boundaries
Atmospheric Electrodynamics probe for THERmal plasma (AETHER); Thermal Plasma Sensor (TPS)	Electric fields
Radiation Environment Monitor (REM)	Energetic particles

NOAA/NESDIS advice needed from Decadal Survey

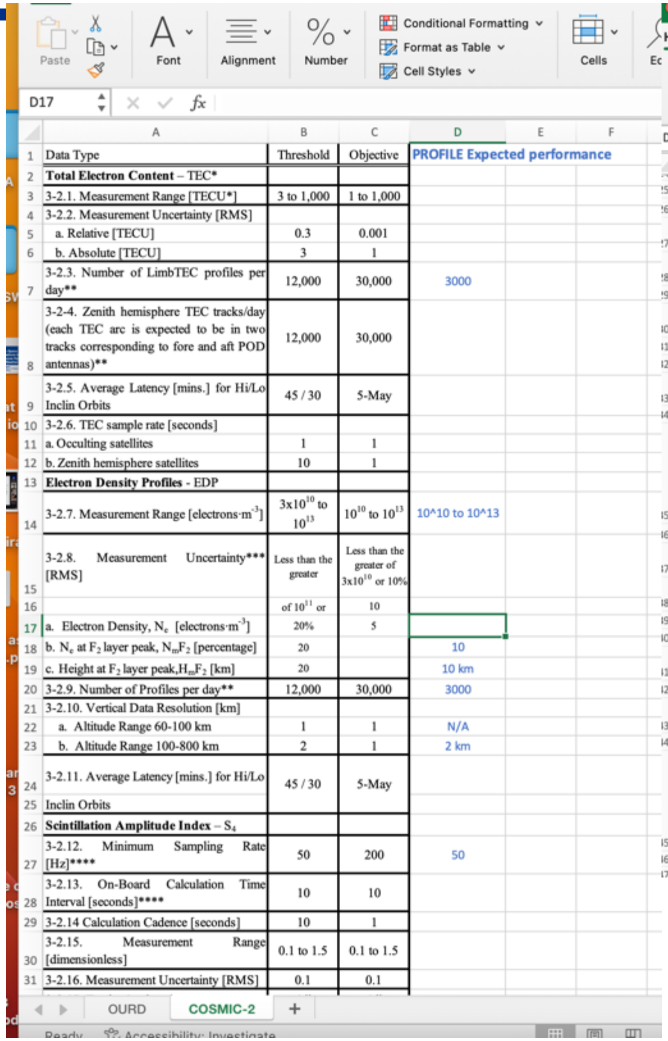
- Concepts and plans for enhancements of capabilities
- Improved understanding of needed latency of notifications to customers; e.g. L1 observation products to electric power industry is nominally one hour or less
- Advice on operational platform systems in order to address critical observational gaps or potential gaps
- Advice on other agency tech demos on NOAA platforms
- Advice on research, tech demos from other agencies to advance understanding of Sun-Earth interactions and the cause and effect of space weather events
- Develop ways to assess and communicate the value proposition for space weather operational observations
- Advice on how to further develop applications and models that fully exploit observational data
- Advice on how operational observations can be used as part of the research infrastructure

Backups

GDC vs. COSMIC-2

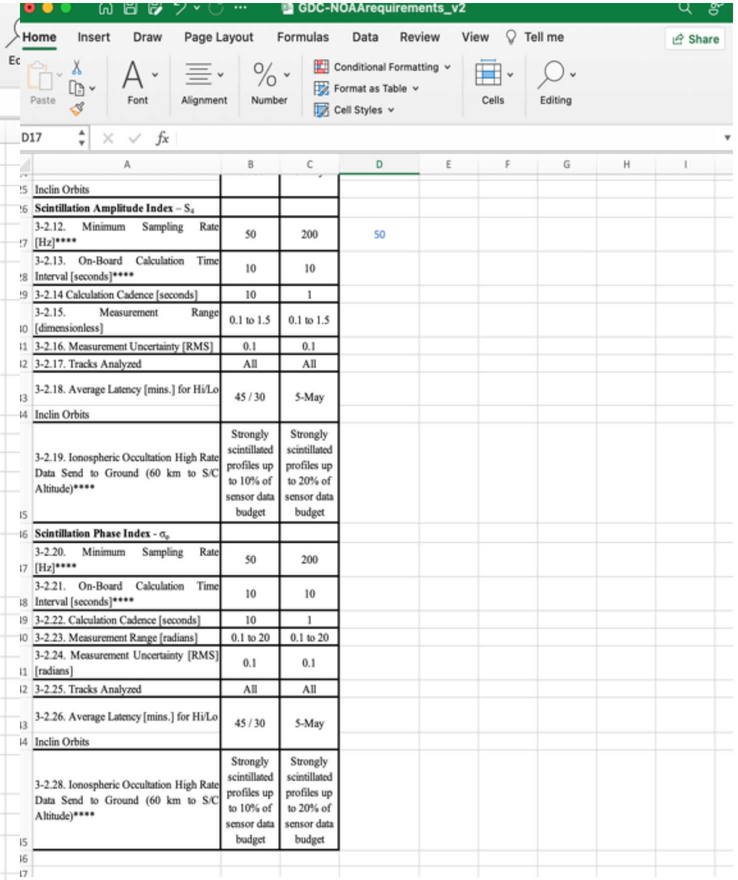


Observation	Geographic Coverage	Vertical Range	Spatial Resolution	Measurement Accuracy	Sampling Interval	Instrument/ Monitor	requirements from:	Service Area Observational User Requirements Document, 2017
Auroral Boundary: LEO		LEO				CAPE		
Auroral Energy Deposition: LEO		LEO				CAPE		
Electric Field: LEO		LEO				TPS, AETHER		
Energetic ions: LEO		LEO				REM		
Geomagnetic Field: LEO		LEO		2 nT	10 / sec	NEMISIS		
Electrons: Medium and High Energy, LEO		LEO				REM		
Ions: Medium and High Energy, LEO		LEO				REM		
Ionospheric Electron Density Profiles		LEO			3000 / day	PROFILE		
Neutral Density		LEO		10%	1 / 2 sec	MoSAIC		
Thermospheric Neutral Winds		LEO		4.5 m/s (3.5 m/s vertical)	1 / 2 sec	MoSAIC		
Aurorae: Supra-Thermal through Auroral Energy Particles, Electrons		LEO		10%	1 / sec	CAPE		
Aurorae: Supra-Thermal through Auroral Energy Particles, Ions		LEO		10%	1 / sec	CAPE		
Thermosphere Temperature		LEO		2%	1 / 2 sec	MoSAIC		
Thermospheric Neutral Composition		LEO		1%	1 / 2 sec	MoSAIC		
Slant Total Electron Content of the Ionosphere		LEO			3000 / day	PROFILE		
Thermal Plasma Density				25/cm^3 or 2%	2 / sec	TPS		
Ion Drift Vector				18 m/s	1 / sec	TPS		

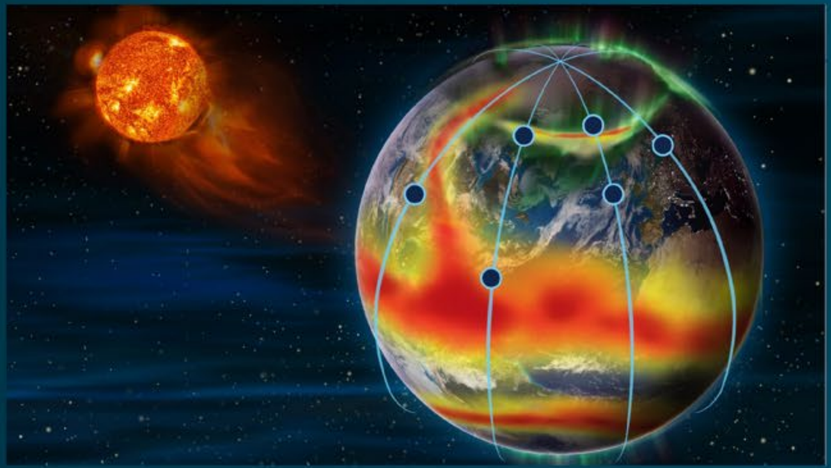


Data Type	Threshold	Objective	PROFILE Expected performance
Total Electron Content – TEC*			
3-2.1. Measurement Range [TECU*]	3 to 1,000	1 to 1,000	
3-2.2. Measurement Uncertainty [RMS]			
a. Relative [TECU]	0.3	0.001	
b. Absolute [TECU]	3	1	
3-2.3. Number of LimbTEC profiles per day**	12,000	30,000	3000
3-2-4. Zenith hemisphere TEC tracks/day (each TEC arc is expected to be in two tracks corresponding to fore and aft POD antennas)**	12,000	30,000	
3-2.5. Average Latency [mins.] for Hi/Lo Inclin Orbits	45 / 30	5-May	
3-2.6. TEC sample rate [seconds]			
a. Occulting satellites	1	1	
b. Zenith hemisphere satellites	10	1	
Electron Density Profiles - EDP			
3-2.7. Measurement Range [electrons·m^{-3}]	$3x10^{10}$ to 10^{13}	10^{10} to 10^{13}	10^10 to 10^13
3-2.8. Measurement Uncertainty*** [RMS]	Less than the greater	Less than the greater of $3x10^{10}$ or 10%	
	of 10^{11} or	10	
a. Electron Density, N_e [electrons·m^{-3}]	20%	5	
b. N_e at F_2 layer peak, N_mF_2 [percentage]	20		10
c. Height at F_2 layer peak, H_mF_2 [km]	20		10 km
3-2.9. Number of Profiles per day**	12,000	30,000	3000
3-2.10. Vertical Data Resolution [km]			
a. Altitude Range 60-100 km	1	1	N/A
b. Altitude Range 100-800 km	2	1	2 km
3-2.11. Average Latency [mins.] for Hi/Lo Inclin Orbits	45 / 30	5-May	
Scintillation Amplitude Index – S_4			
3-2.12. Minimum Sampling Rate [Hz]****	50	200	50
3-2.13. On-Board Calculation Time Interval [seconds]****	10	10	
3-2.14 Calculation Cadence [seconds]	10	1	
3-2.15. Measurement Range [dimensionless]	0.1 to 1.5	0.1 to 1.5	
3-2.16. Measurement Uncertainty [RMS]	0.1	0.1	

OURD | COSMIC-2



A	B	C	D
Inclin Orbits			
Scintillation Amplitude Index – S_4			
3-2.12. Minimum Sampling Rate [Hz]****	50	200	50
3-2.13. On-Board Calculation Time Interval [seconds]****	10	10	
3-2.14 Calculation Cadence [seconds]	10	1	
3-2.15. Measurement Range [dimensionless]	0.1 to 1.5	0.1 to 1.5	
3-2.16. Measurement Uncertainty [RMS]	0.1	0.1	
3-2.17. Tracks Analyzed	All	All	
3-2.18. Average Latency [mins.] for Hi/Lo Inclin Orbits	45 / 30	5-May	
3-2.19. Ionospheric Occultation High Rate Data Send to Ground (60 km to S/C Altitude)****	Strongly scintillated profiles up to 10% of sensor data budget	Strongly scintillated profiles up to 20% of sensor data budget	
Scintillation Phase Index - σ_φ			
3-2.20. Minimum Sampling Rate [Hz]****	50	200	
3-2.21. On-Board Calculation Time Interval [seconds]****	10	10	
3-2.22. Calculation Cadence [seconds]	10	1	
3-2.23. Measurement Range [radians]	0.1 to 20	0.1 to 20	
3-2.24. Measurement Uncertainty [RMS] [radians]	0.1	0.1	
3-2.25. Tracks Analyzed	All	All	
3-2.26. Average Latency [mins.] for Hi/Lo Inclin Orbits	45 / 30	5-May	
3-2.28. Ionospheric Occultation High Rate Data Send to Ground (60 km to S/C Altitude)****	Strongly scintillated profiles up to 10% of sensor data budget	Strongly scintillated profiles up to 20% of sensor data budget	

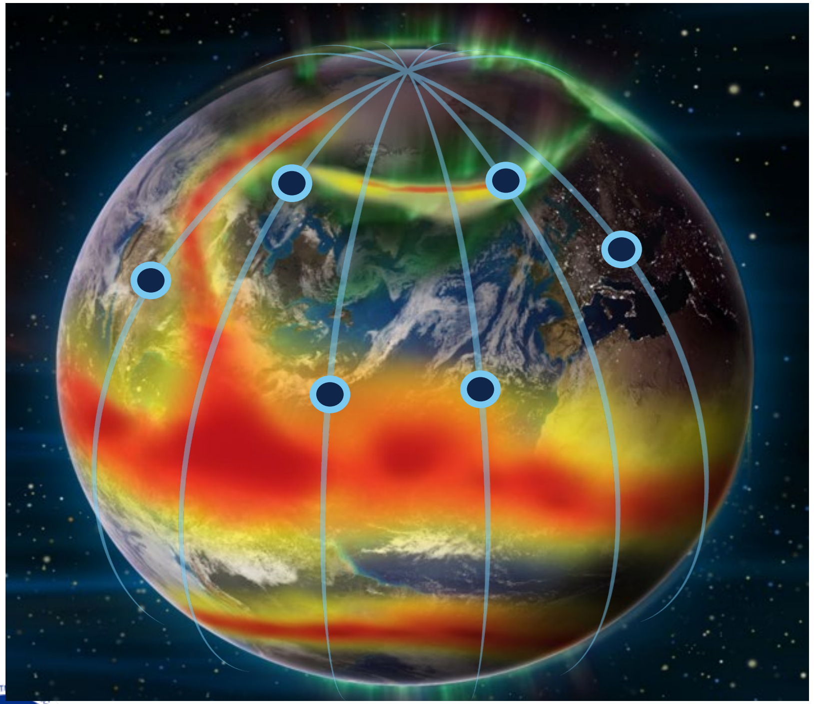


Geospace Dynamics Constellation (GDC) Independent Review Board (IRB) Report

Co-Chair - O. Figue roa
Co-Chair - M. Hagan

The GDC Mission

6 polar-orbiting satellites at ~375 km
6 science instruments
3 interdisciplinary science teams
1 radiation environment monitor (REM)
Precise Orbit Determination for
GNSS neutral density cross-calibration



Science Instruments:

- AETHER Langmuir probe (PI Andersson, CU Boulder)
- MoSAIC ion/neutral mass spec (PI Benna, UMBC)
- CAPE auroral precipitation (PI Gershman, GSFC)
- TPS Thermal plasma (PI Anderson, UT Dallas)
- NEMESIS Magnetometer (PI Moldwin, U of Michigan)
- PROFILE GNSS-RO (PI Verkhoglyadova, JPL)

Interdisciplinary Science Teams:

- NEXUS (PI Thayer, CU Boulder): GNSS neutral density; real-time space weather experience (GOLD & IMAP)
- ADAPTIVE (PI Bishop, Aerospace Corp): model/data connection & visualization; space weather expertise
- SOPHIE (PI Deng, UT Arlington): multiscale forcing from above

GDC Architecture

- Baseline mission: Six spacecraft (6 identical sets of instruments) in different inclinations 81-82 degrees/400Km orbits, differential procession separates the orbit planes as they precess in local time
  - Important to launch 6 S/C to protect the integrity of the minimum required (5) to meet science objectives in 3 years
- Threshold mission: Four spacecraft address highest priority science objectives in the STDT