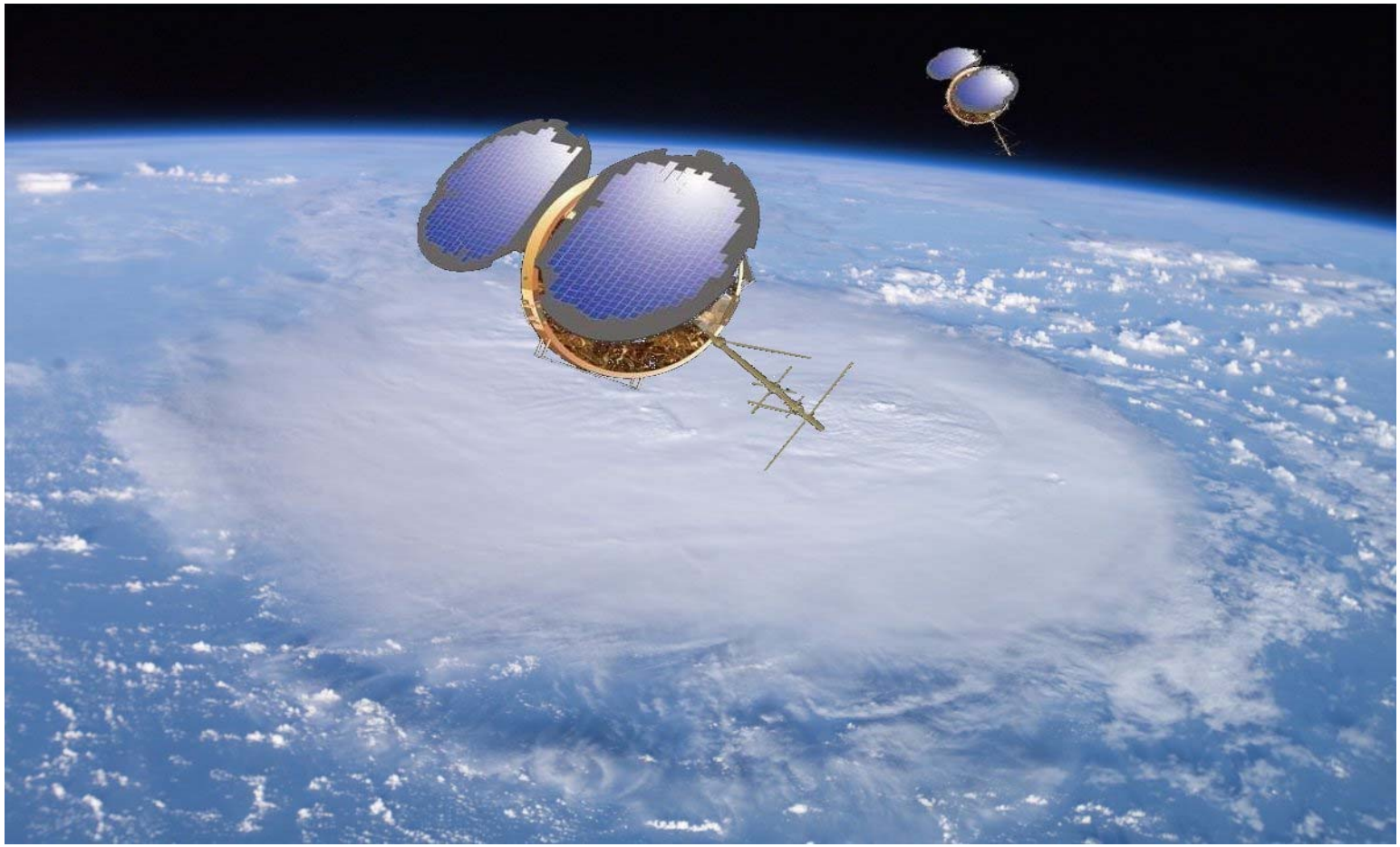
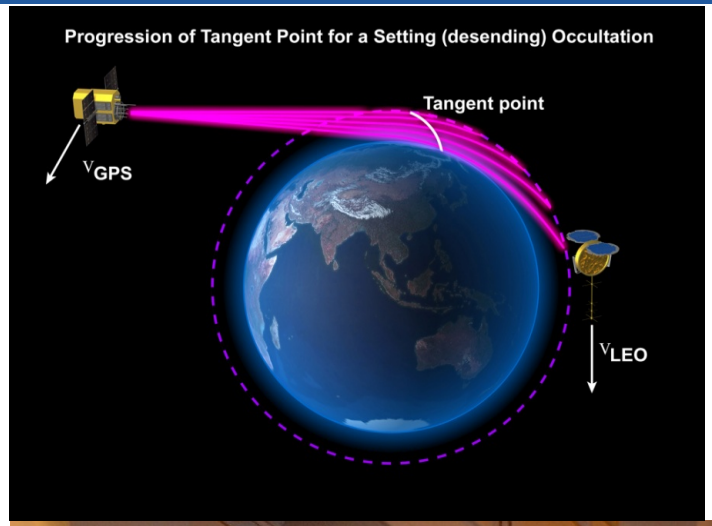
Plans for a 12 Satellite GNSS RO Constellation (COSMIC-2/FORMOSAT-7)



Dave Ector – NOAA
Lidia Cucurull – NOAA
Pete Wilczynski – NOAA
6 September 2010

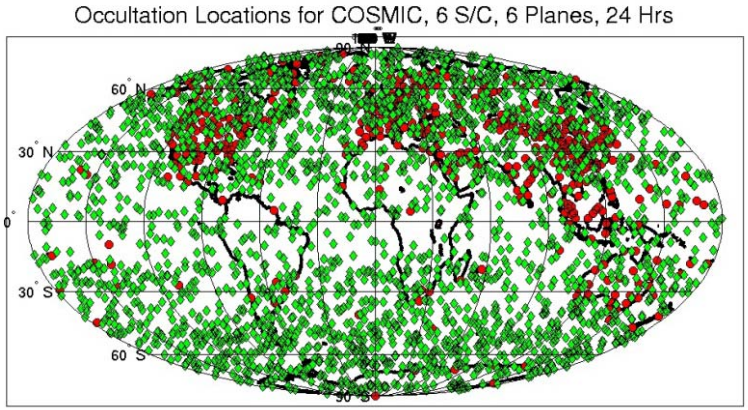
COSMIC-1– Current constellation

- Launched April 2006
- US (NSF)/Taiwan Collaboration
- 6 Orbital microsatellites
- Provides 1800-2500 worldwide all weather soundings per day
- Very high accuracy temperature profiles - approaching 0.1K
- Very high accuracy electron density profiles – 10%, 0.001 TECU, 0.1 S4 index uncertainty
- NOAA operational forecasting with the data started May 2007
- Significant positive impacts on weather forecasting
- Constellation beginning to degrade - 2011
- NOAA cannot afford a data gap

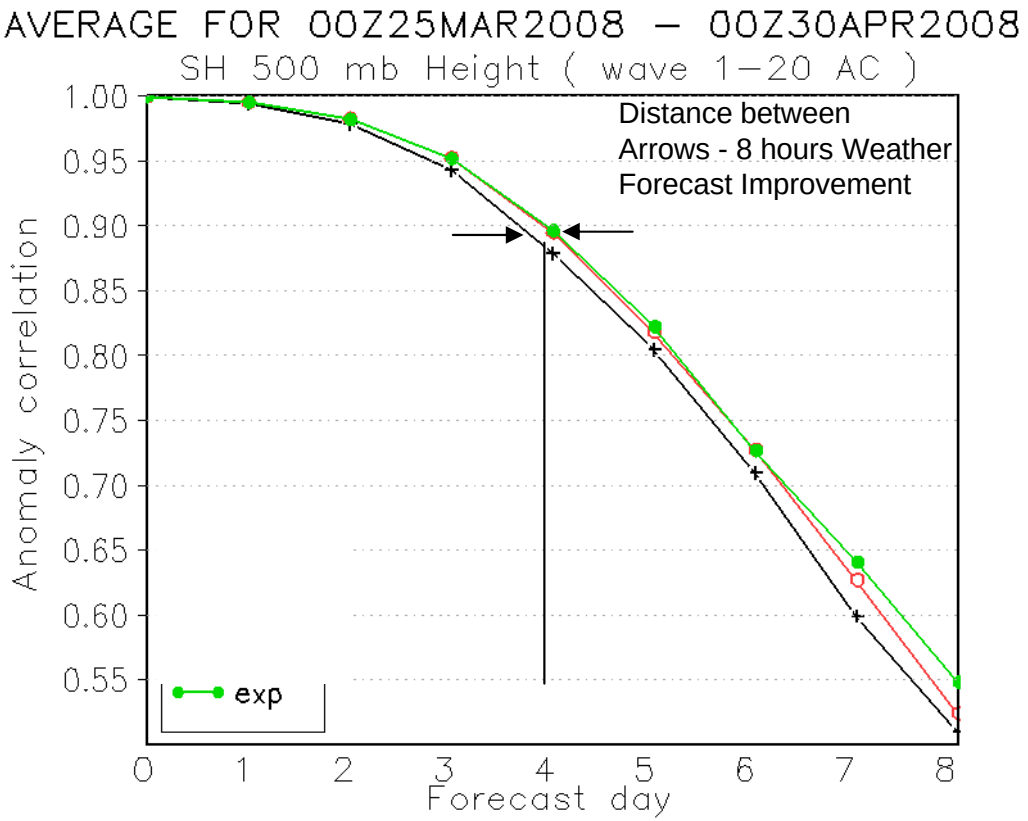


6 COSMIC - Significant Impact Weather Service Forecast Skill

- Proven significant forecast accuracy improvement
- 40-day experiments:
  - **Black line - No COSMIC**
  - **Red line - COSMIC Initial Operations**
  - **Green line -** Current COSMIC



Daily - COSMIC vs Radiosondes



-COSMIC provides 8 hours of improvement in Weather forecast skill at day 4 and over 15 hours in day 7
- Particularly significant improvement over the oceans
- Analysis – COSMIC satellite loss causes significant NOAA forecast skill loss

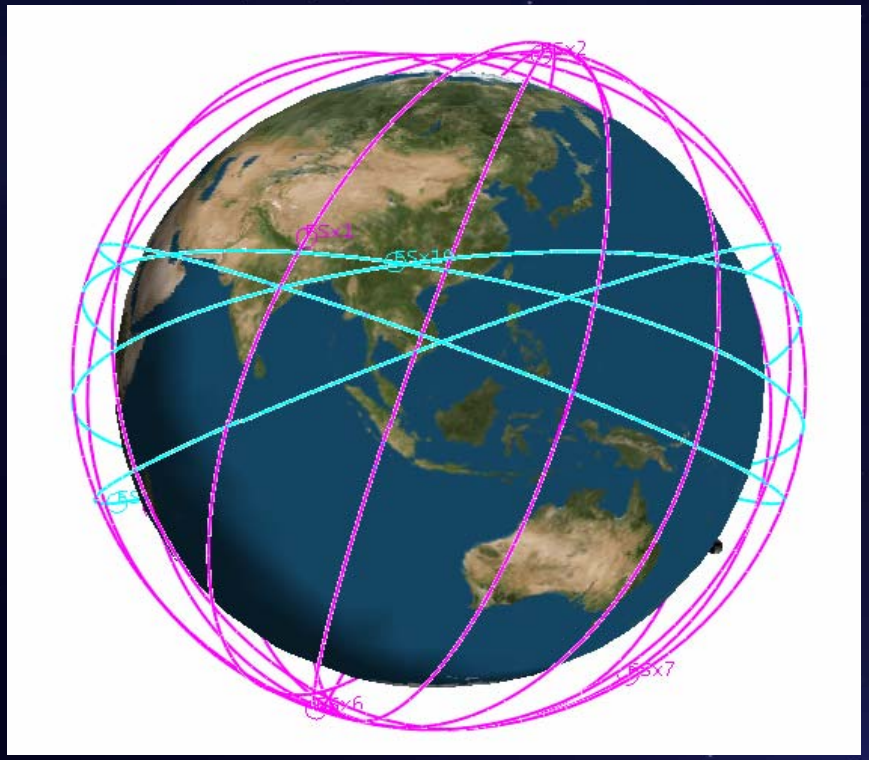
Courtesy of Lidia Cucurull – NOAA/NCEP

COSMIC 2 Plans - Continued US/Taiwan Partnership

- COSMIC beginning to degrade
- Data gap expected by 2014-2015 due to loss of satellites
- President's Budget supports first of 2 launches of COSMIC 2 constellation by mid 2014
- Partnership to build and launch a 12 satellite constellation
  - NSPO/Taiwan to provide: 12 spacecraft buses and integration of payloads onto spacecraft, Mission Control Center
  - NOAA to provide: 12 GNSSRO Payloads, 2 launches, tracking stations, payload data processing
  - First launch planned for mid 2014 – 2nd launch 2016 (TBD)
  - Goal is to provide 12,000 + worldwide atmospheric and ionospheric soundings per day

COSMIC-1 and COSMIC-2 Coverage

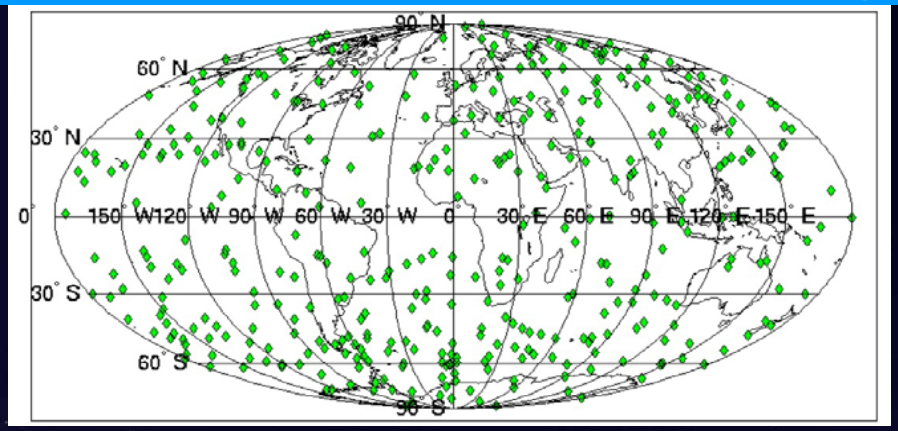
1500-2200 Soundings per day vs 10,000 – 14,000 soundings per day



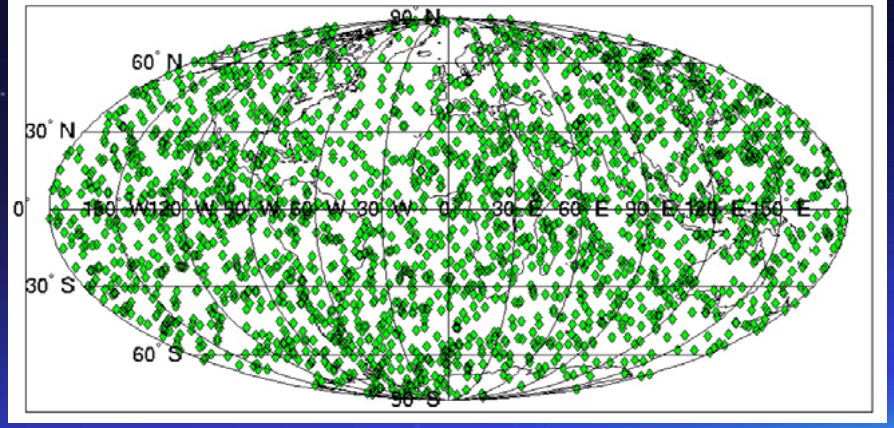
Multiple Inclinations

Data is distributed more homogeneously

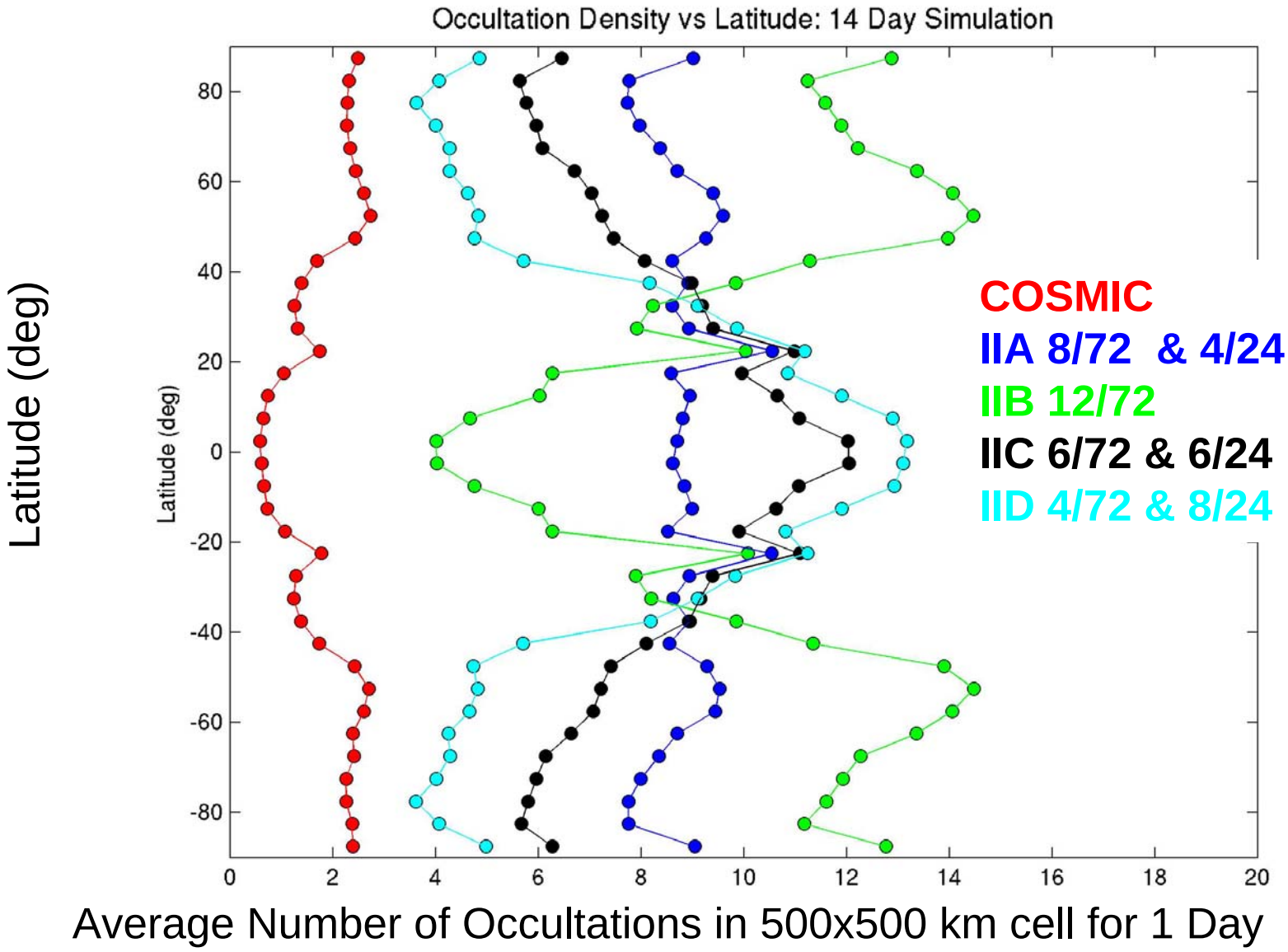
COSMIC / FORMOSAT-3 Occultations–3 Hrs Coverage



COSMIC-2 Occultations – 3 Hrs Coverage



Occultation Density vs Latitude: 14 Day Simulation



Courtesy Bill Schreiner, UCAR

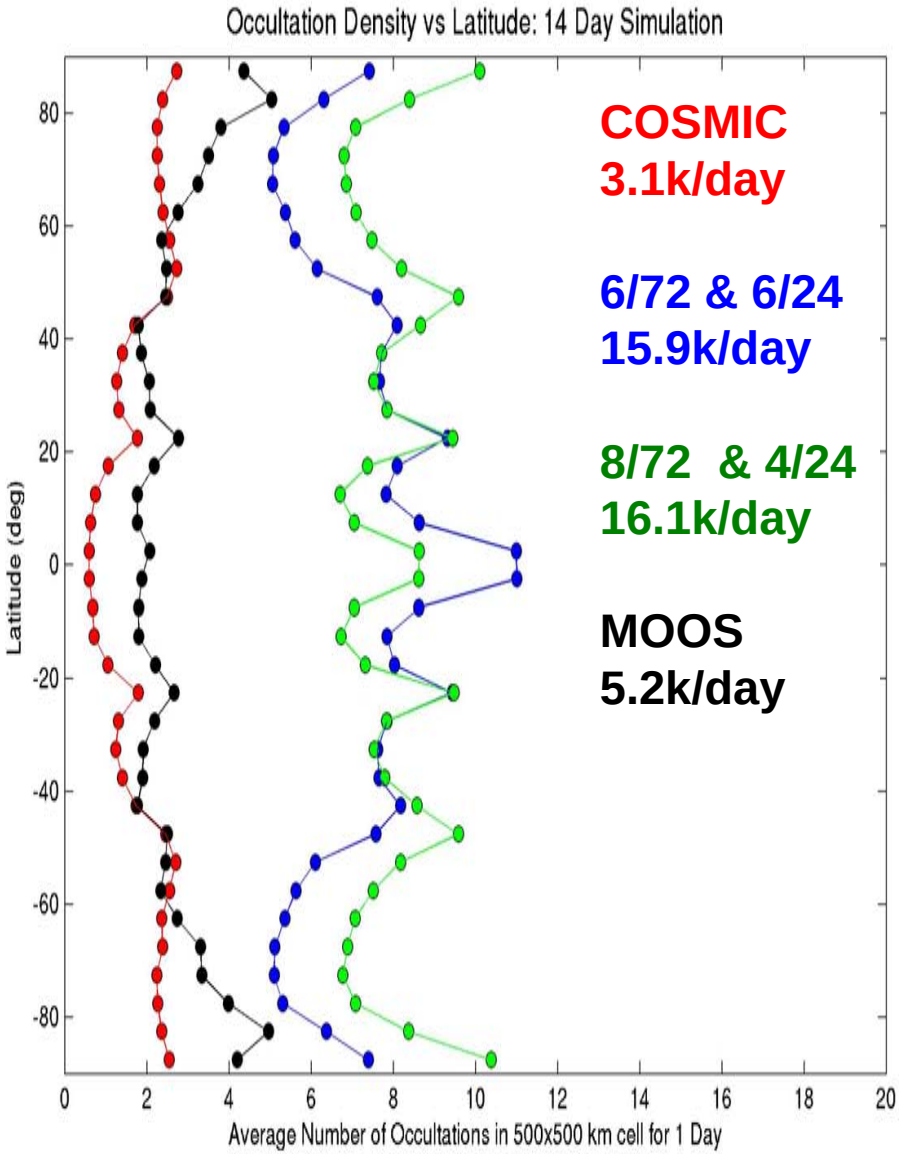
Possible International Missions In the C-2 Timeframe

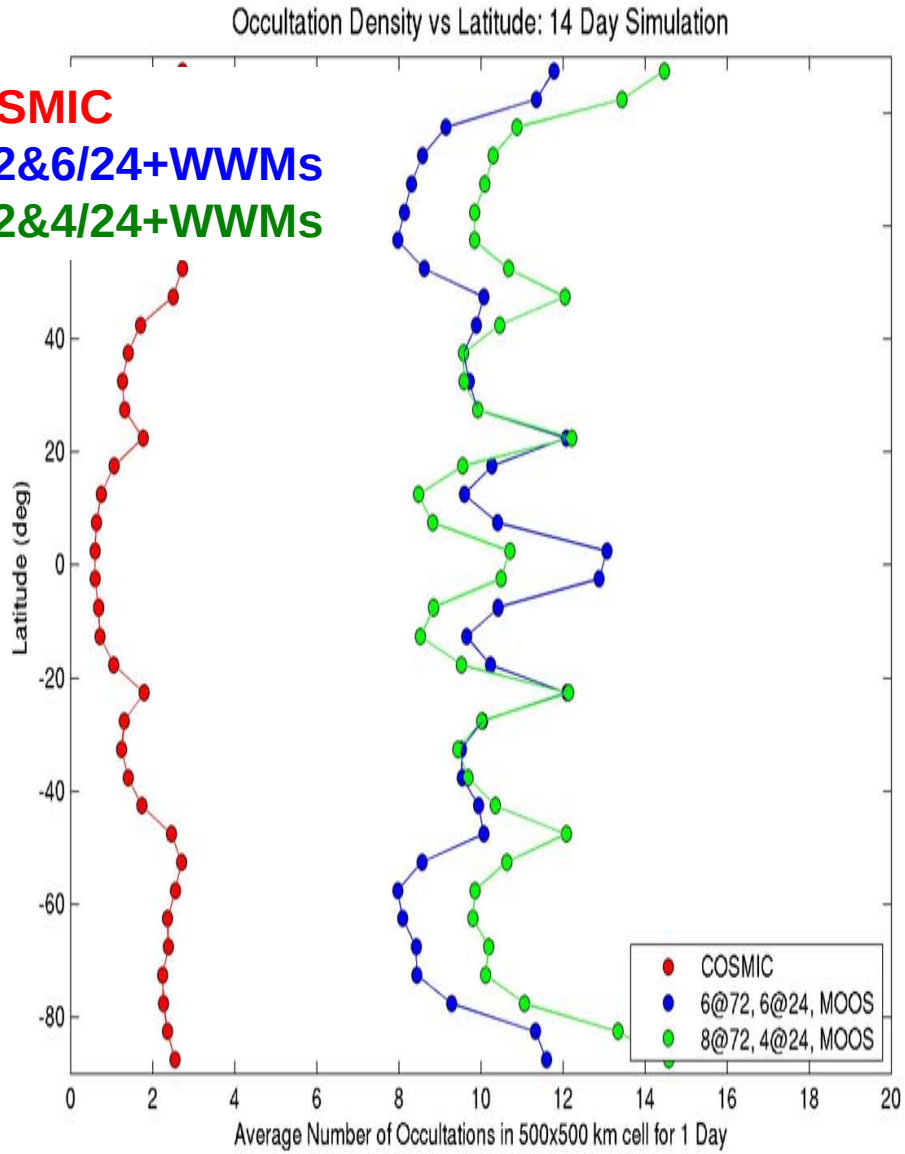
Mission	Launch-Duration	GNSS RO Payload	Orbit (alt/inc/ LT)	# Occs Per day	Operational/Real-Time
F7/C2	2015	JPL TriG (GPS,Galileo)	800km/72,24°/-	>10,000	Yes
METOP-B	2012	GRAS (GPS)	817km/98.7°/09:30LT	~600	Yes
OceanSat-2	2009	ROSA (GPS)	720km/98.3°/12:00LT	~500	No
KOMPSAT-5	2010	IGOR+ (GPS)	685km/98.5°/06:00LT	~500	No
Megha-Tropiques	TBD	ROSA (GPS)	867km/20°/-	~500	No
SAC-D	TBD	ROSA (GPS)	657km/98.5°/10:15LT	~500	No
TanDEM-X	20	IGOR (GPS)	514km/97.4°/18:00LT	~500	No
PAZ	2012	IGOR+ (GPS)	510km/97.4°/-	~500	No
EQUARS	2012	IGOR (GPS)	750km/20°/-	~500	No
CNOFS	2008	BlackJack (GPS)	853/405km/13°/-	~250	-

6@72, 6@24(800km)

12 S/C with GPS+Galileo

Add worldwide missions



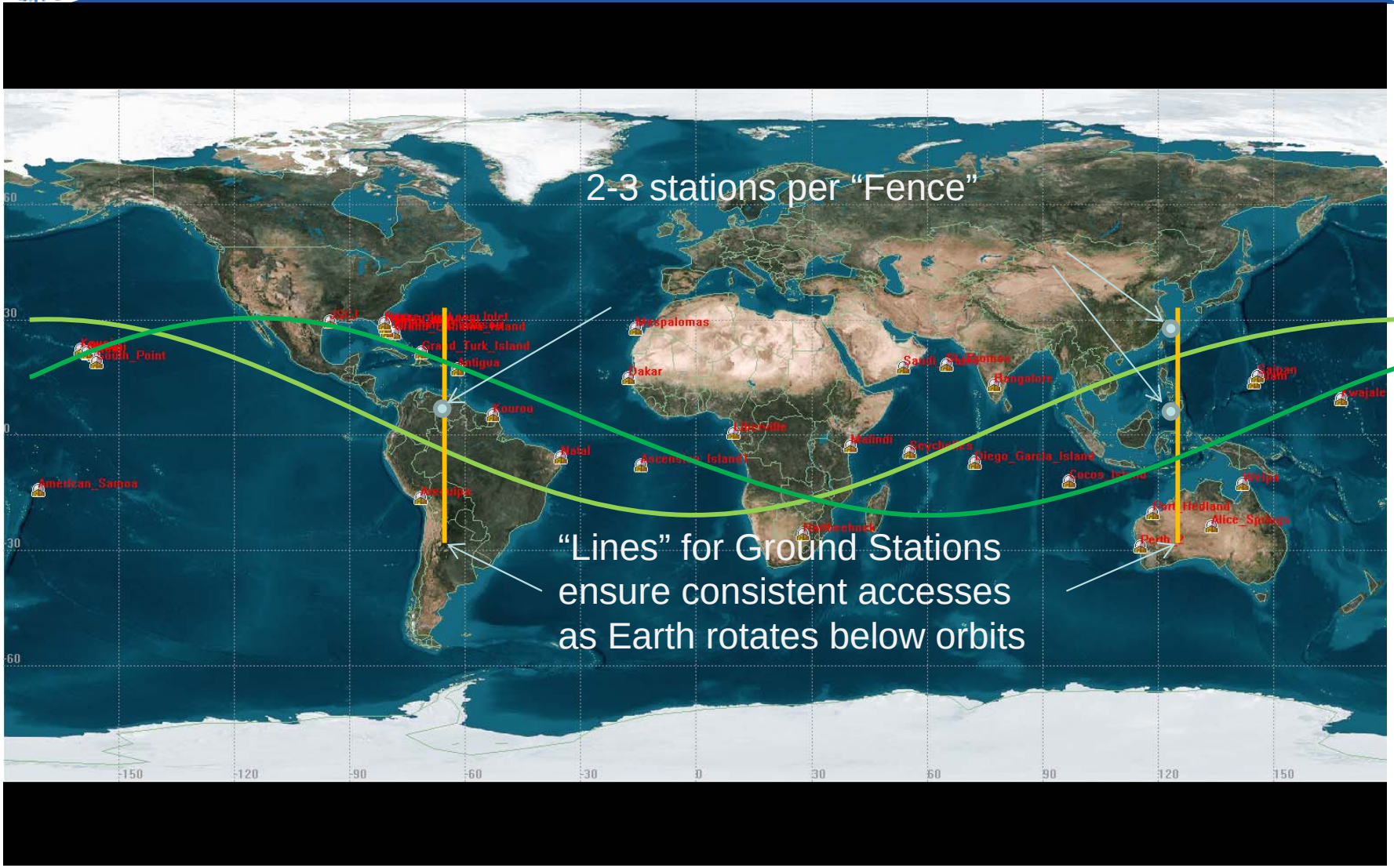


Courtesy Bill Schreiner, UCAR

Baseline - Architecture that enhances equatorial collection

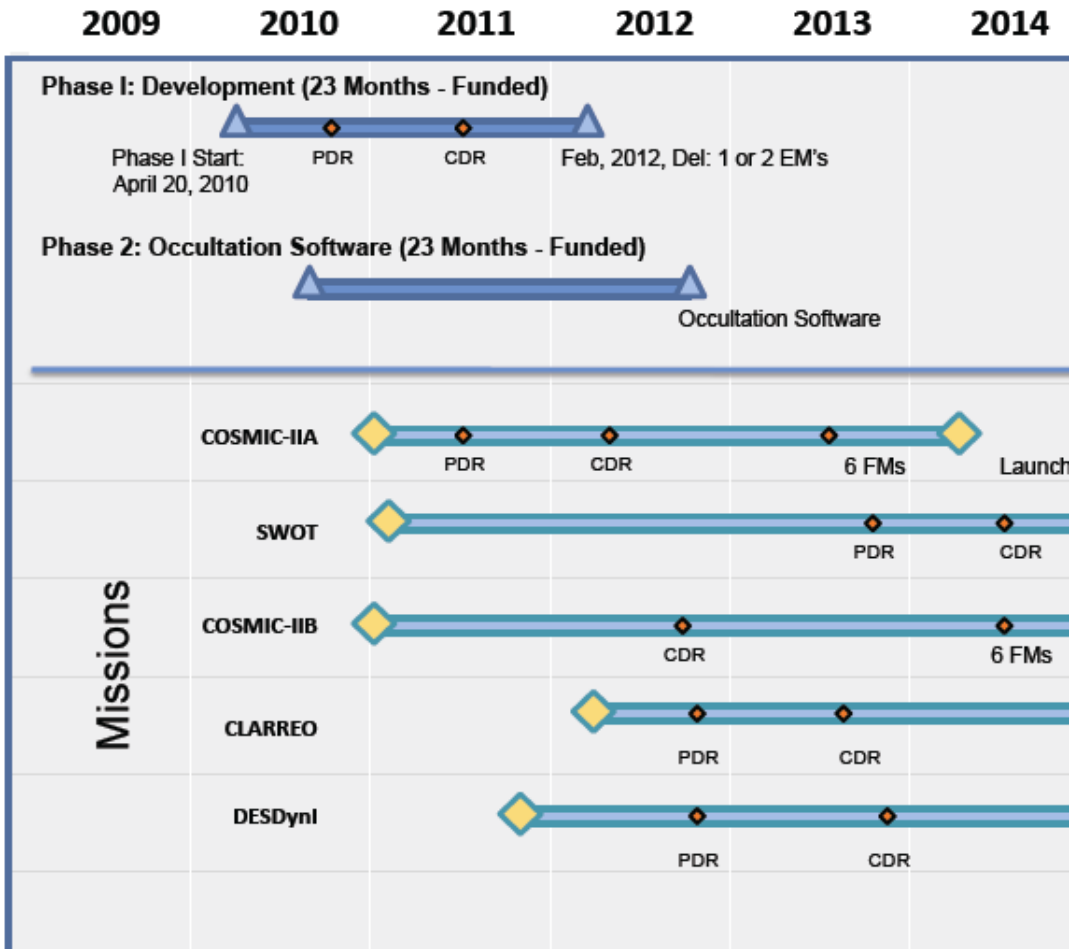
- 6 satellites at 24 degrees – 6 at 72 degrees
  - Even distribution of soundings if overlaid on international missions (tend to be polar)
  - Only requires 2 launches instead of 3 (lower cost)
- 45 minute avg data latency – 2 data dumps per orbit
  - Requires 4 polar ground stations – 2 at each pole
  - Requires 4-6 stations in +/- 25 degree region – spacing is under study
- Use of TDRSS is under study for lower inclination (NASA satellite to satellite links)
  - Could provide 15 minute latency
  - High cost of radios
  - High power requirements – up to 50 watts

Equatorial Station “Fences”



NOAA C-2 Development – GNSSRO Payload

- Plan to utilize Jet Propulsion Laboratory (JPL) and UCAR to manage the COSMIC-2 payloads/processing – similar to COSMIC
  - Payloads – Design of JPL GNSSRO Payload (TriG) started in April '10 (NASA Funded project)

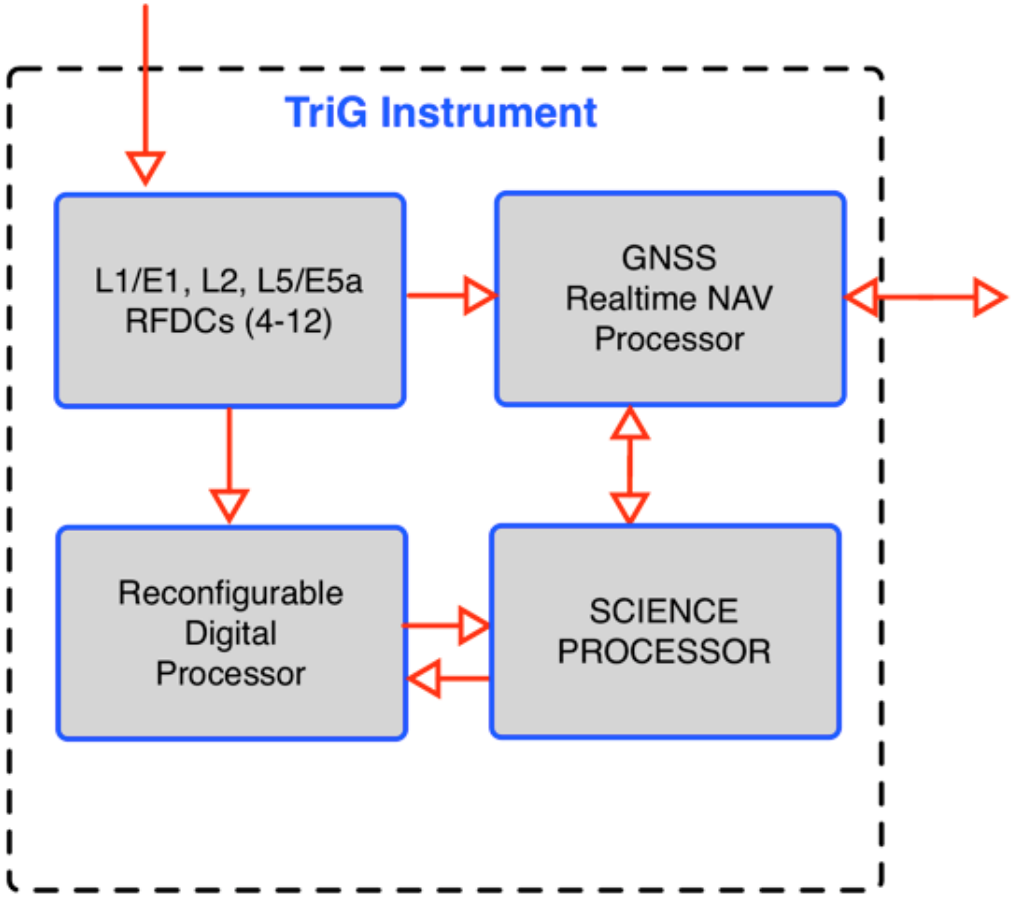


NASA/JPL TriG Payload Design

- TriG GNSS Receiver is being design by JPL in partnership with Broad Reach Engineering (BRE)
- JPL is responsible for Management, System Engineering, RF Front-end and Antenna development, Signal Processing Algorithm development and implementation, and performance verification, and deliver qual. EM unit
- BRE will be responsible for mechanical, thermal, and electrical design build, assembly, integrate and test, environmental.

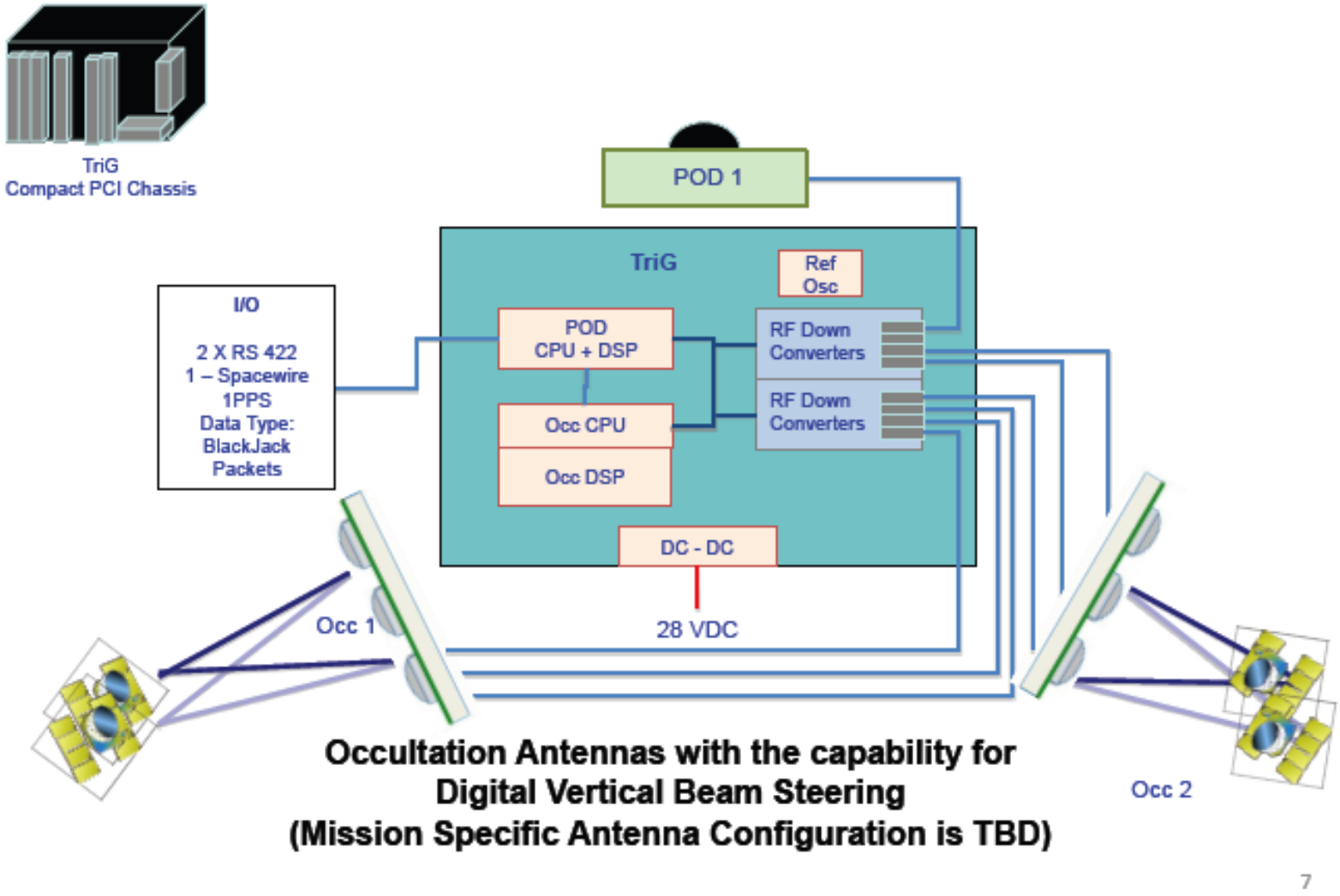
TriG GNSSRO Payload (1)

- TriG
  - Mass – 6 kg
  - Power – 50 Watts
  - Volume – 30 X 30 X 20 cm
  - Antenna inputs - 8
- GNSS Realtime Nav Processor
  - Acquires and tracks GNSS signals
  - Sets Real Time Clock
  - Generates Position, Velocity and Time
  - Outputs time-tagged phase/range/snr
  - Sends nav data to Science Processor
- Science Processor
  - Schedules Iono/Atmo Occ Profiles
  - Extracts 1ms phase/range/amp
  - Formats observables



Courtesy - JPL

TriG GNSS RO Payload (2)



Courtesy - JPL

C-2 Ground Development

- Payload Data Processing – GNSSRO payload – UCAR to upgrade the CDAAC capability for COSMIC 2.
- 24/7 Operational Processing capability to be deployed to NOAA – Suitland
- Processing capability deployed to TACC – Taiwan

GNSSRO Mission Data Availability

- Concerns about data policy of international science missions
- Very slow availability of data – even for testing
- Data will be critical to fill "gap" between COSMIC 1 and 2
- How can data availability be improved?
  - Need early access to both processed and raw GNSSRO data from our international partners
  - International agreements
  - Will try to make C-2 data available right away – within 2-3 months like C-1

C-2 Schedule

Activity Name	Duration (Work Months)	Start Date	Finish Date
COSMIC Operations	39.14	1/1/08	4/20/11
COSMIC Extended life	33.14	4/1/11	1/16/14
COSMIC 2 Spacecraft Development (Taiwan)	50.99	9/8/10	12/25/14
Ground Development	**60.93**	**12/31/10**	**1/25/16**
Equatorial Stations (1st	36.09	12/31/10	1/17/14
Equatorial Stations (2nd	36.14	1/2/12	1/19/15
Antarctica Stations	48.18	1/2/12	1/25/16
Receiver Development	**50.40**	**4/23/10**	**7/1/14**
Payload Development	49.17	4/23/10	6/16/14
Delivery 6 Flight Units	0.00	7/1/13	7/1/13
Delivery 6 Flight Units	0.00	7/1/14	7/1/14
Payload Processing Development	18.05	10/1/12	4/9/14
Rocket Procurement	30.94	11/16/12	6/26/15
Launch 1	0.00	7/1/14	7/1/14
Launch 2	0.00	6/1/16	6/1/16