



The CICERO Project

(Community Initiative for Continuing Earth Radio Occultation)

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A Community Approach to GNSS Radio Occultation

4th IROWG Workshop
Melbourne, Australia
22 April 2015



Thought For The Day

“Be thou as chaste as ice, as pure
as snow, thou shalt not escape
calumny.”

– Hamlet (III, i)

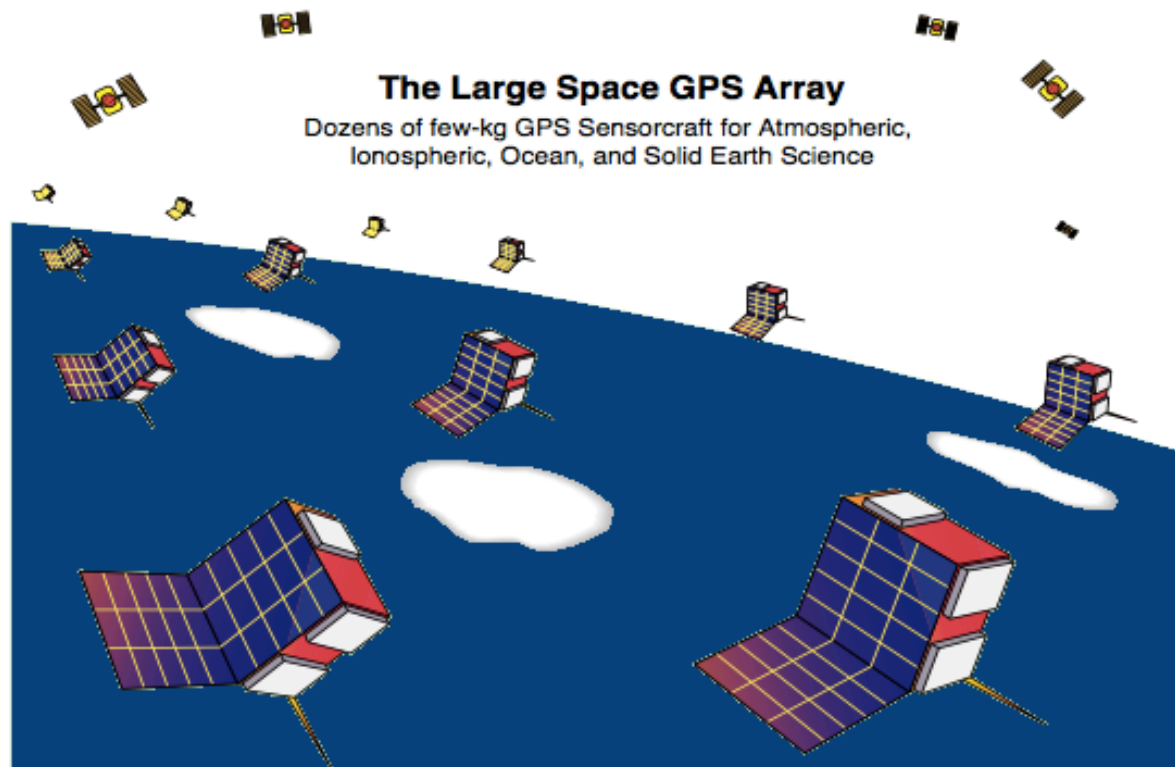


My writings c. 1998

Implications for the Future

In one view, the COSMIC model will be taken to its logical extreme: flight systems will be further miniaturized and we will see dedicated constellations of dozens or even hundreds of tiny free-flyers, each with a mass of a few kilograms, consuming less than 10 watts, and costing a few hundred thousand dollars each to produced in volume (Fig.).

*The roots
early 196
ploited ro*





Happy 20th Anniversary! (for GPS-MET)



Where We Stand Today

0.5 GRACE (13 yrs old)

4.5 COSMIC (9 yrs old)

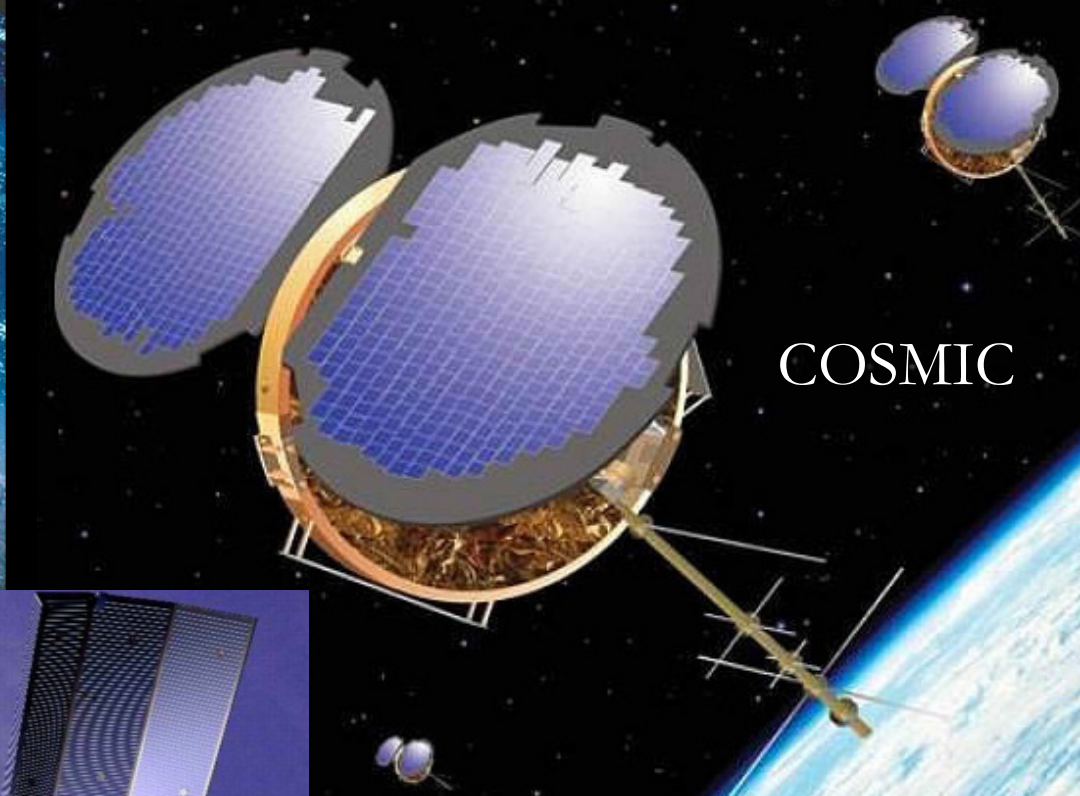
2 METOP (7.5 & 2 yrs old)

0.5 TerraSAR-X (7 yrs old?)

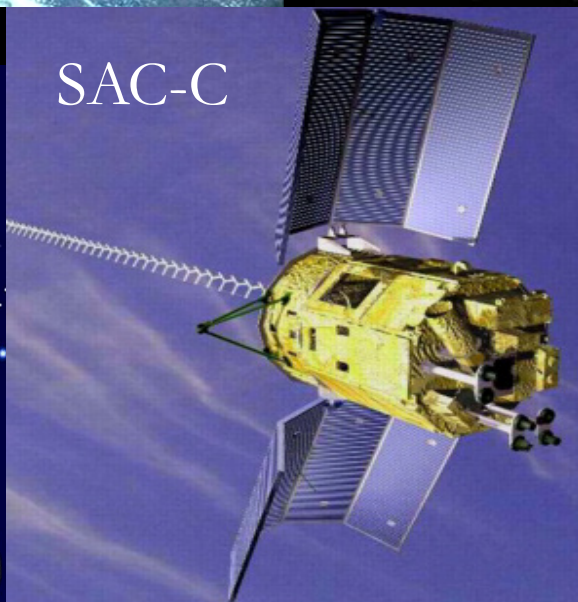
CHAMP



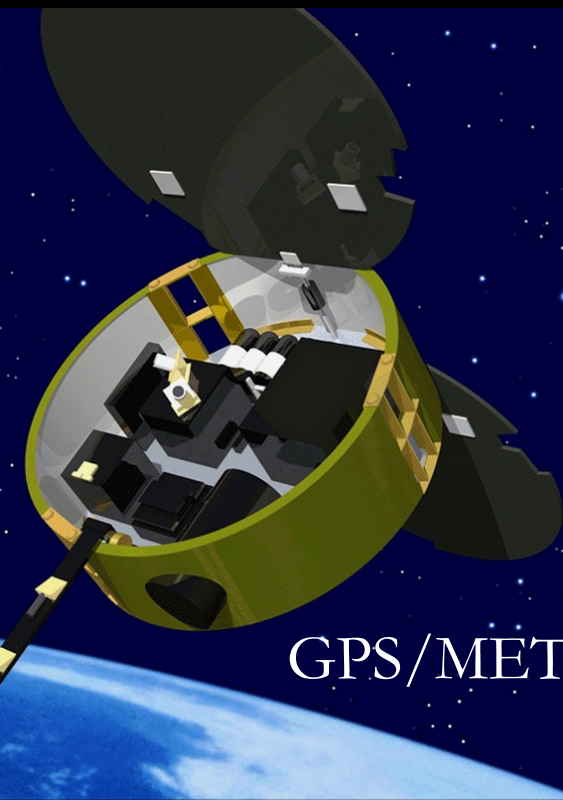
COSMIC



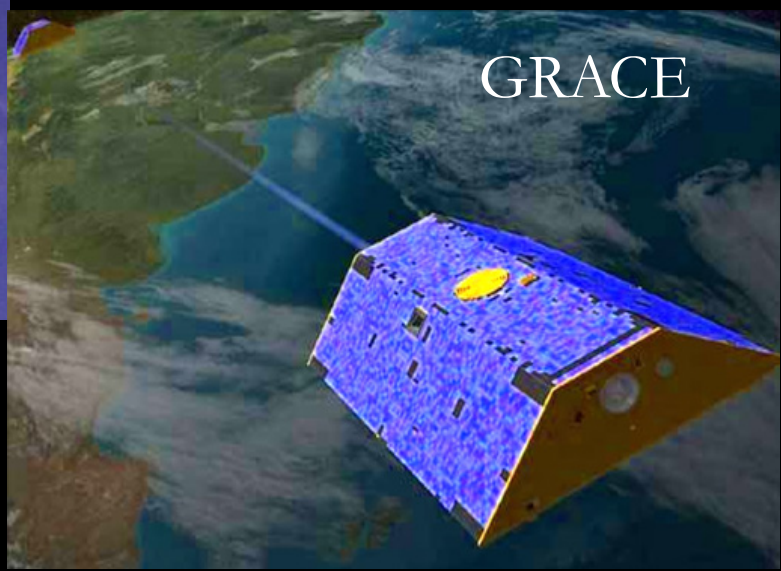
SAC-C



GPS/MET



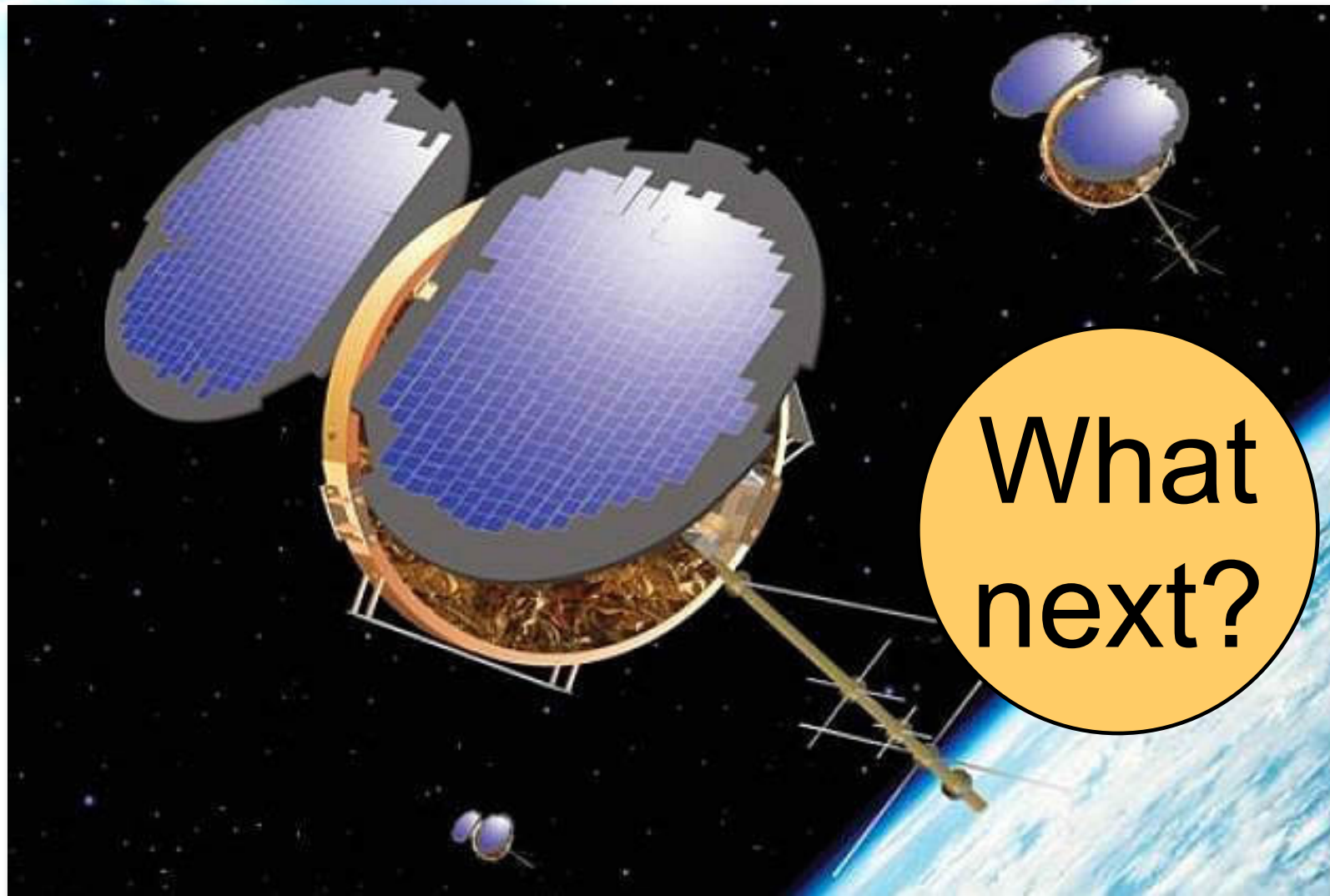
GNSS RO
1995 - 2007



GRACE

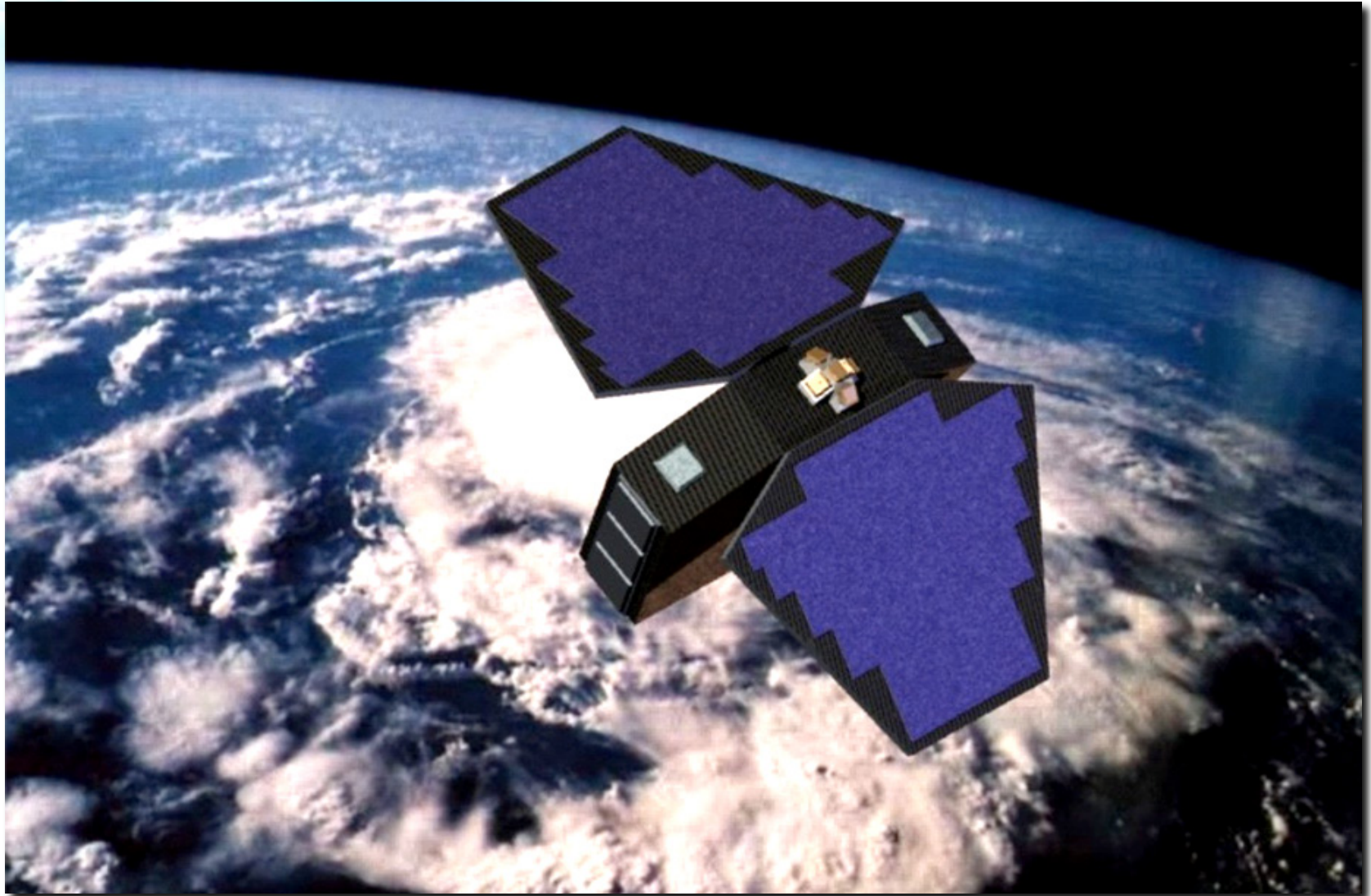


COSMIC: 2006 – ?



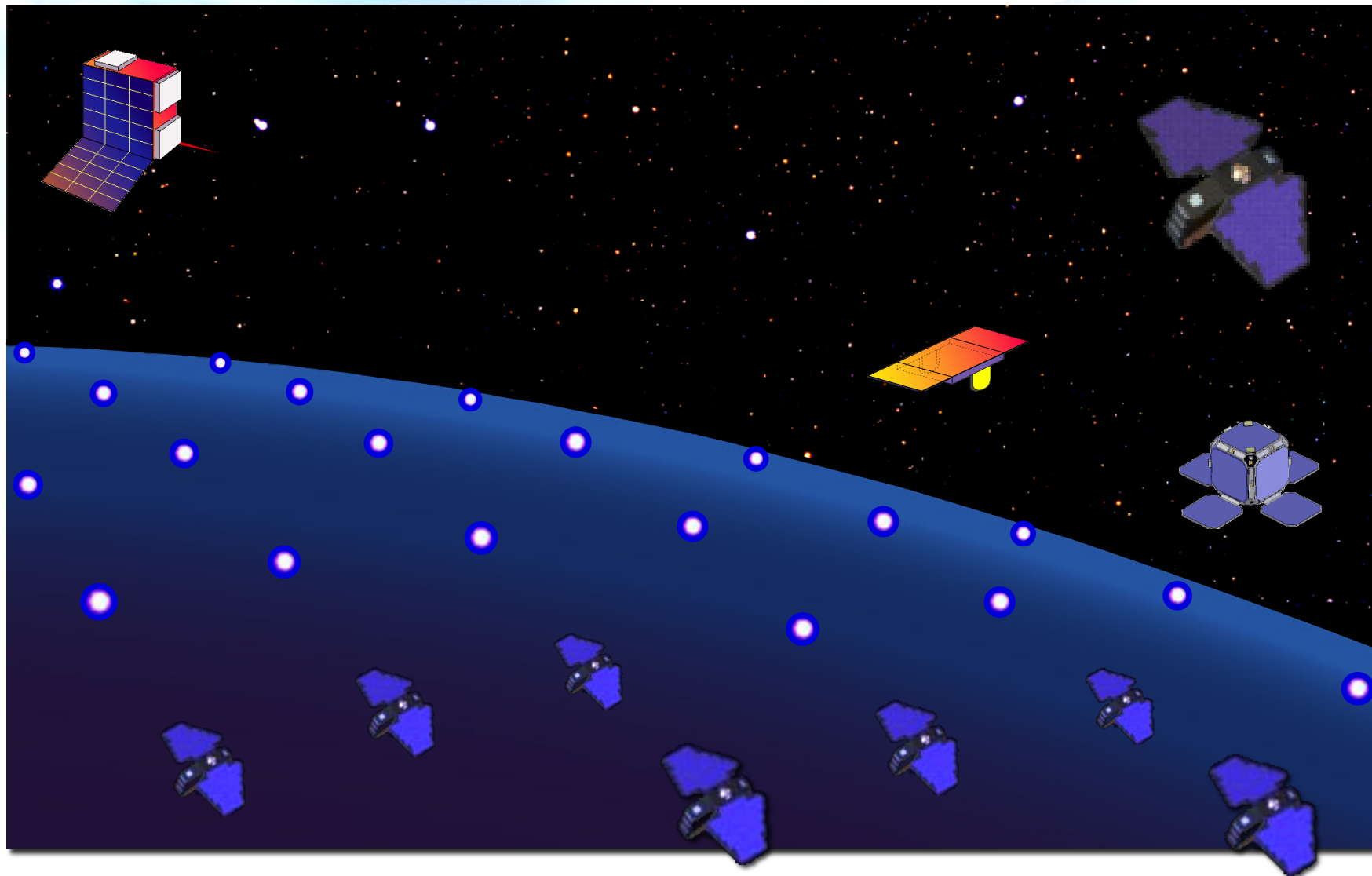


COSMIC-2 (c. 2004) and What Else ??





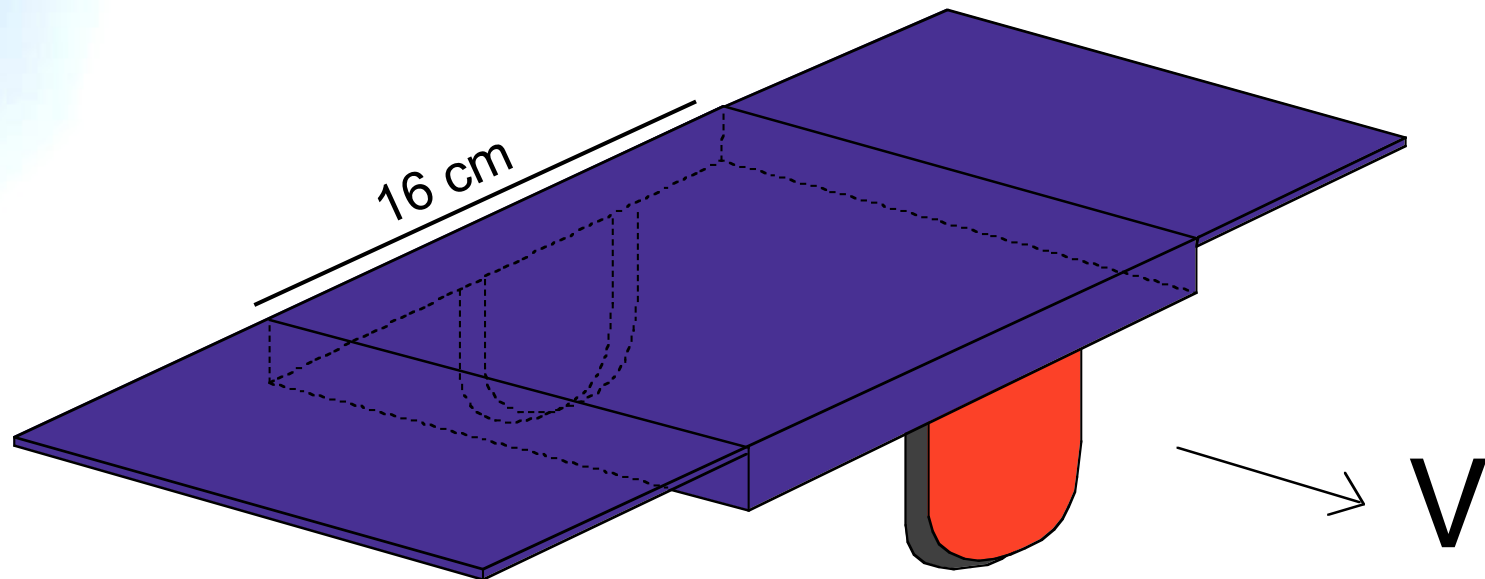
Dense RO Constellations





Twenty-Year Vision

GPS-RO Nanosat Concept (< 1 kg)



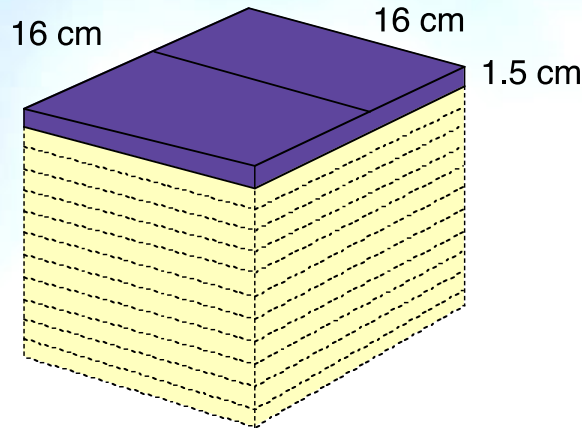
2 May 1995



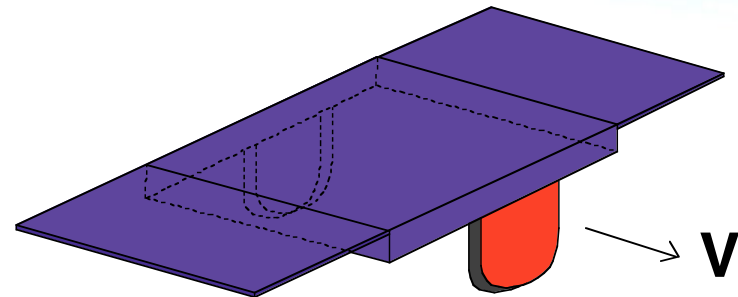
Twenty-Year Vision

Nov 1995

12 STOWED



ONE DEPLOYED

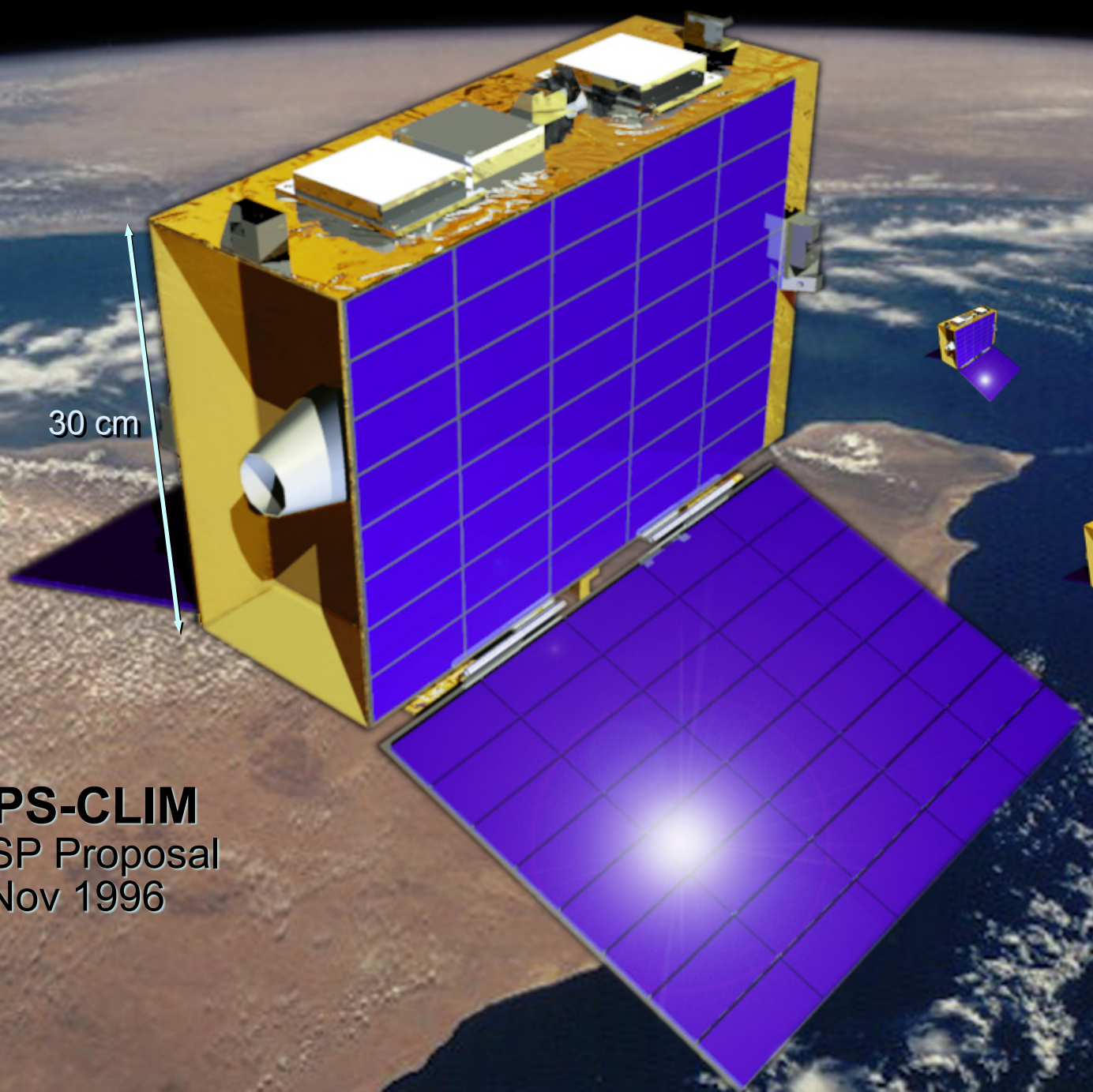


KEY TECHNOLOGIES

Flight GPS-on-a-chip
Single-board spacecraft
Fully autonomous spacecraft
Thin film patch antennas
Precision nano-accelerometer
Cell phone up- and downlink
Auto-nav and attitude determ.
3-axis magnetic stabilization

SPECS & FEATURES

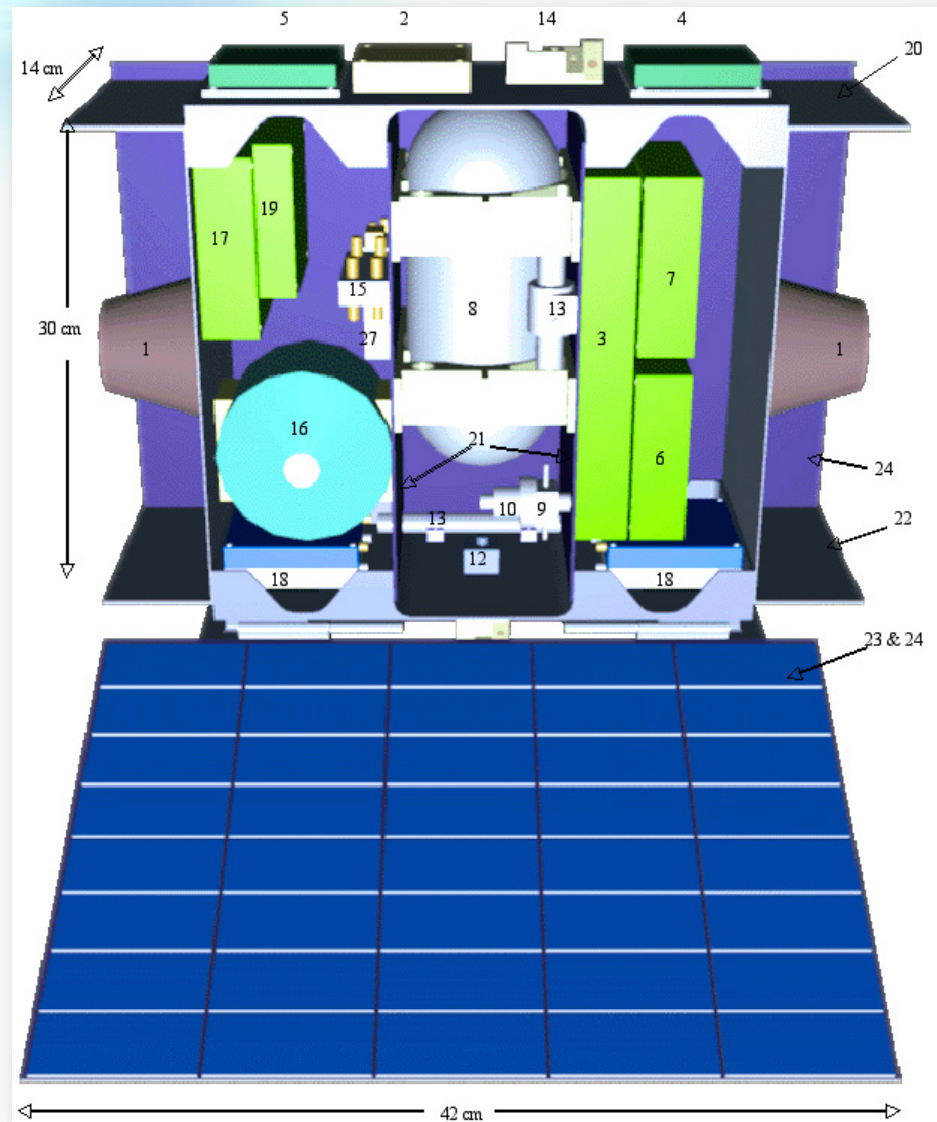
- Total mass: 1 kg per sat
- Volume: $<1000 \text{ cm}^3$
 - Avg power: $<4 \text{ w}$
 - Data rate: $<20 \text{ Mbyte/day}$
 - Onboard Storage: 20 Mbytes
 - GPS attitude determination
 - Spring-release deployment
- Recur. cost-to-orbit: \$100K ea.



GPS-CLIM
ESSP Proposal
Nov 1996



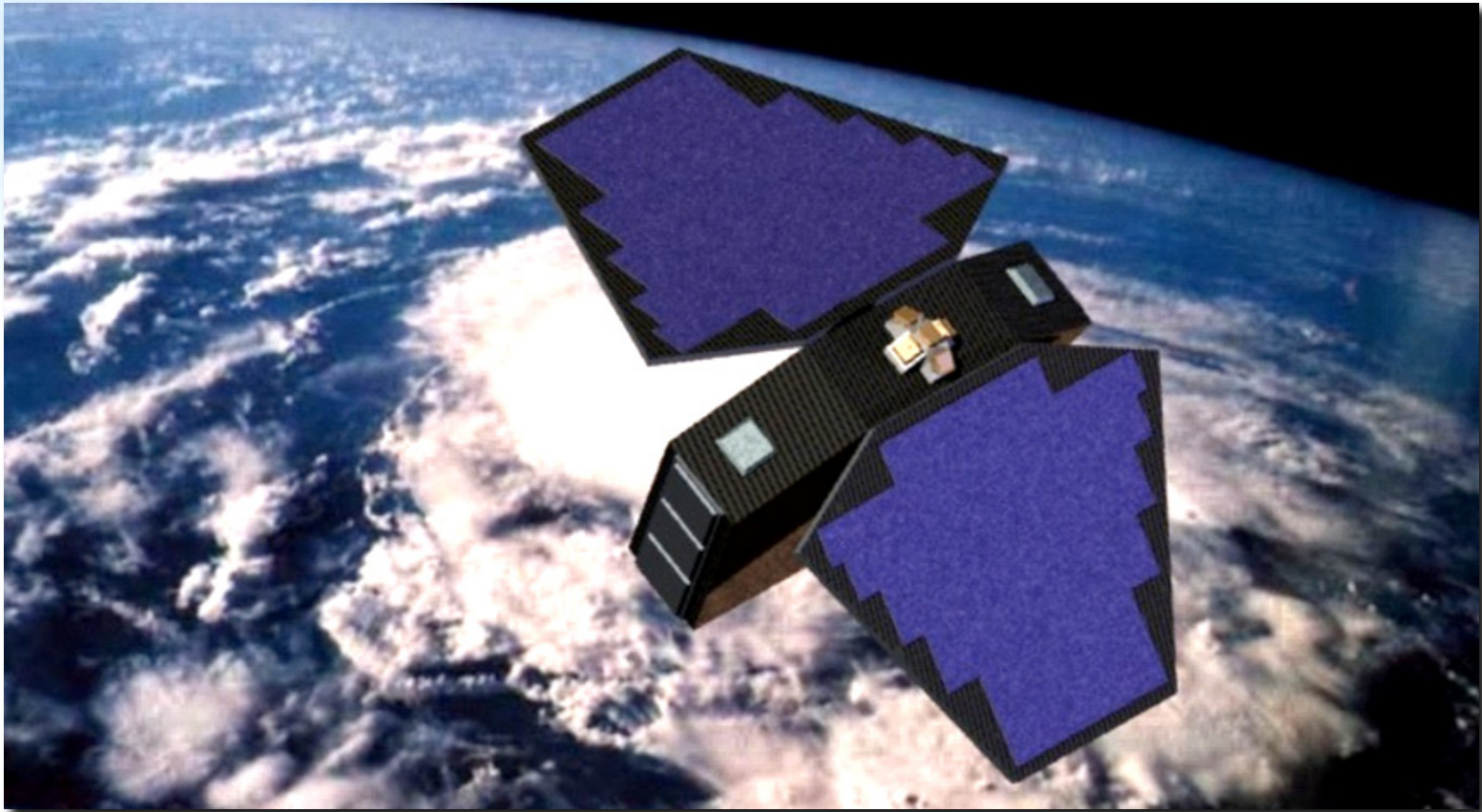
GPS-CLIM: Cutaway





Back to 2007...

The 1996 GPS-CLIM design was the basis for the BRE COSMIC-2 design (below) and the 2007 CICERO design.



Instrument: IGOR 1.5

Broad Reach Engineering



Back to 2007...

At the Oct 2007 COSMIC Data Users
Meeting we were hyping a launch date in
2011

(as was COSMIC-2)



Based On What?

The *CICERO* Project

**Commercial Data Pricing and Feasibility Study for
GNSS Radio Occultation and Ocean Scatterometry**

Final Report

**Submitted to the
National Oceanic and Atmospheric Administration**

by



Dec 30, 2008

geooptics.com/report.pdf



Quoted Prices (2008-10)

Six Polar RO Satellites

All RO Products	2010	2011	2012	2013	2014	2015
Fee (FY10 M\$)	10	10	10	10	10	10
No. of CICERO sats		6	6	6	6	6
Atmos RO profiles/day		4,586	5,242	5,897	6,552	6,552

Twelve Polar RO Satellites

All RO Products	2010	2011	2012	2013	2014	2015
Fee (FY10 M\$)	15	15	15	15	15	15
No. of CICERO sats		12	12	12	12	12
Atmos RO profiles/day		9,173	10,483	11,794	13,104	13,104

geooptics.com/report.pdf



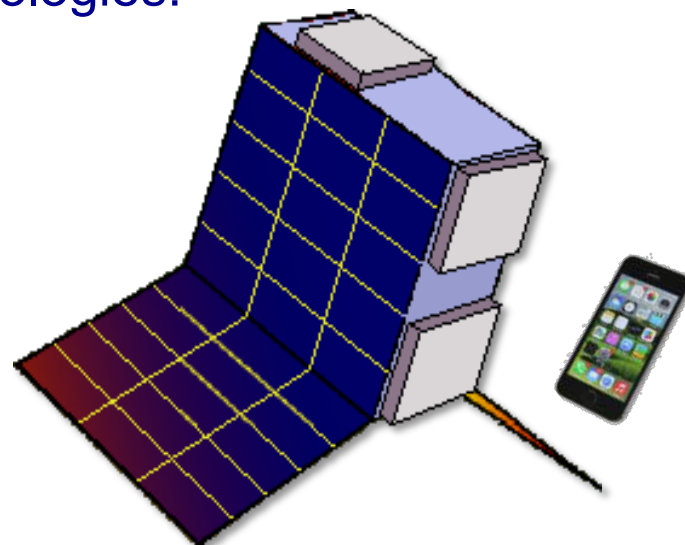
The Situation Today (2015)



- Earth observing programs are in crisis
- Governments can't meet soaring costs
- Critical weather data gaps are looming



GeoOptics was formed to address this crisis with advanced micro-technologies:





A Paradox:

Satellite and space instrument costs have soared to staggering levels...

...while technology costs everywhere else have plummeted.

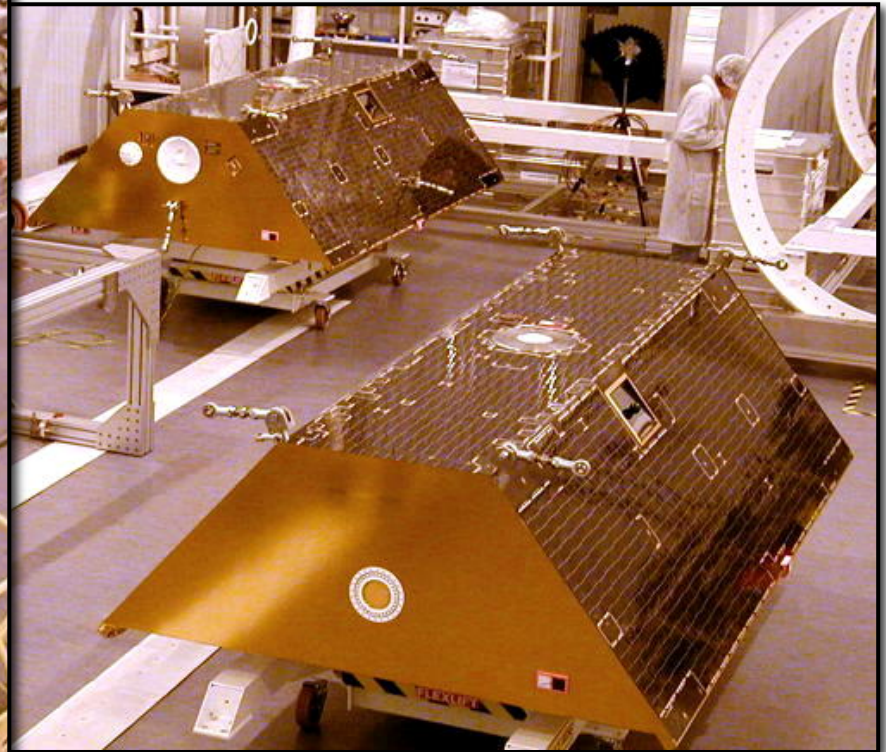


This trend is not sustainable...

...and severely limits the amount of environmental information we can acquire from space.



GRACE: A Case Study



Total Cost:
~\$280M in FY15 \$



Costs In FY15 \$US

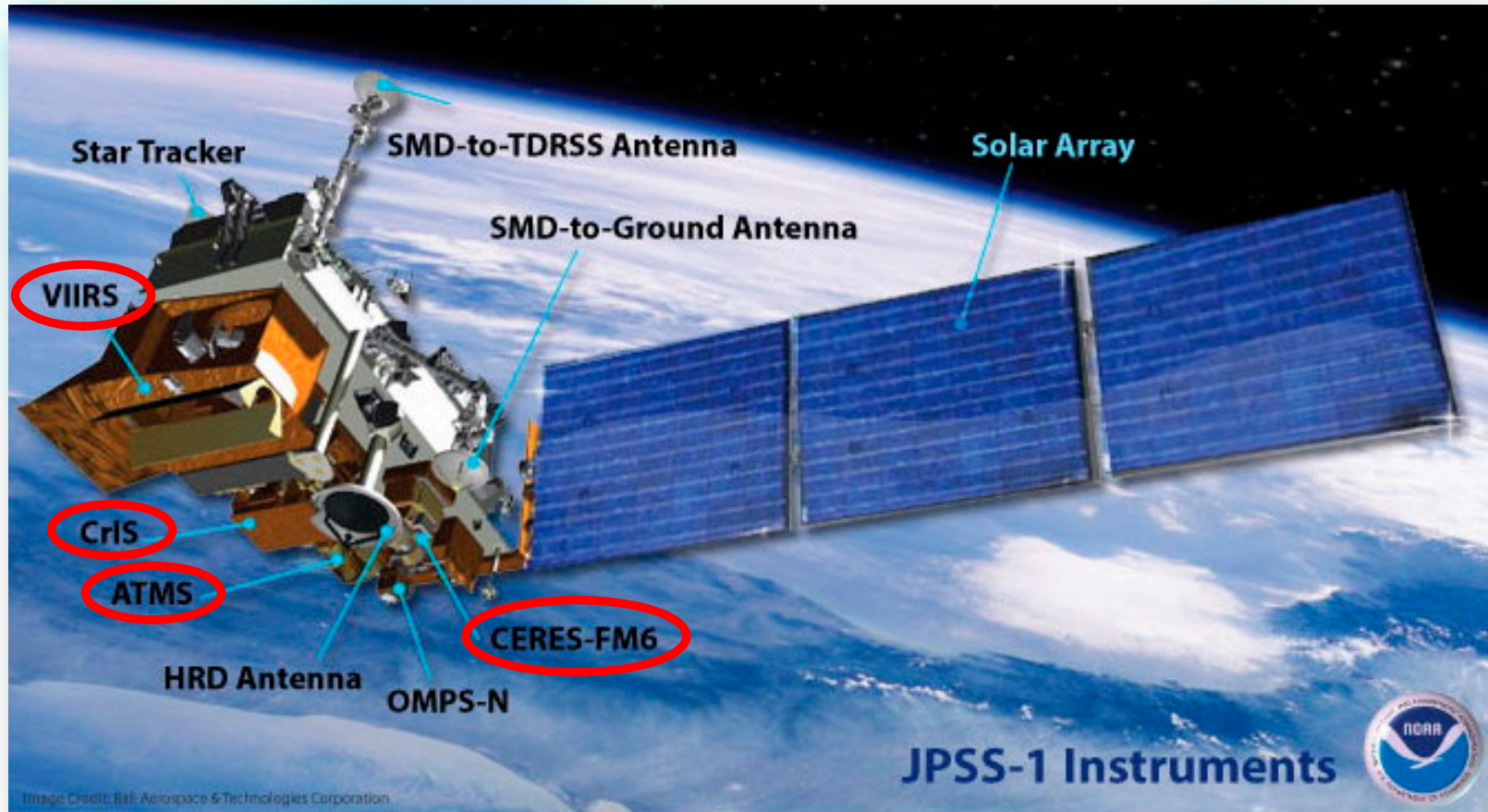
GRACE: ~\$280M

GRACE-FO: ~\$560M

Repeat of GRACE
Heritage design
15y of tech advance



JPSS Today

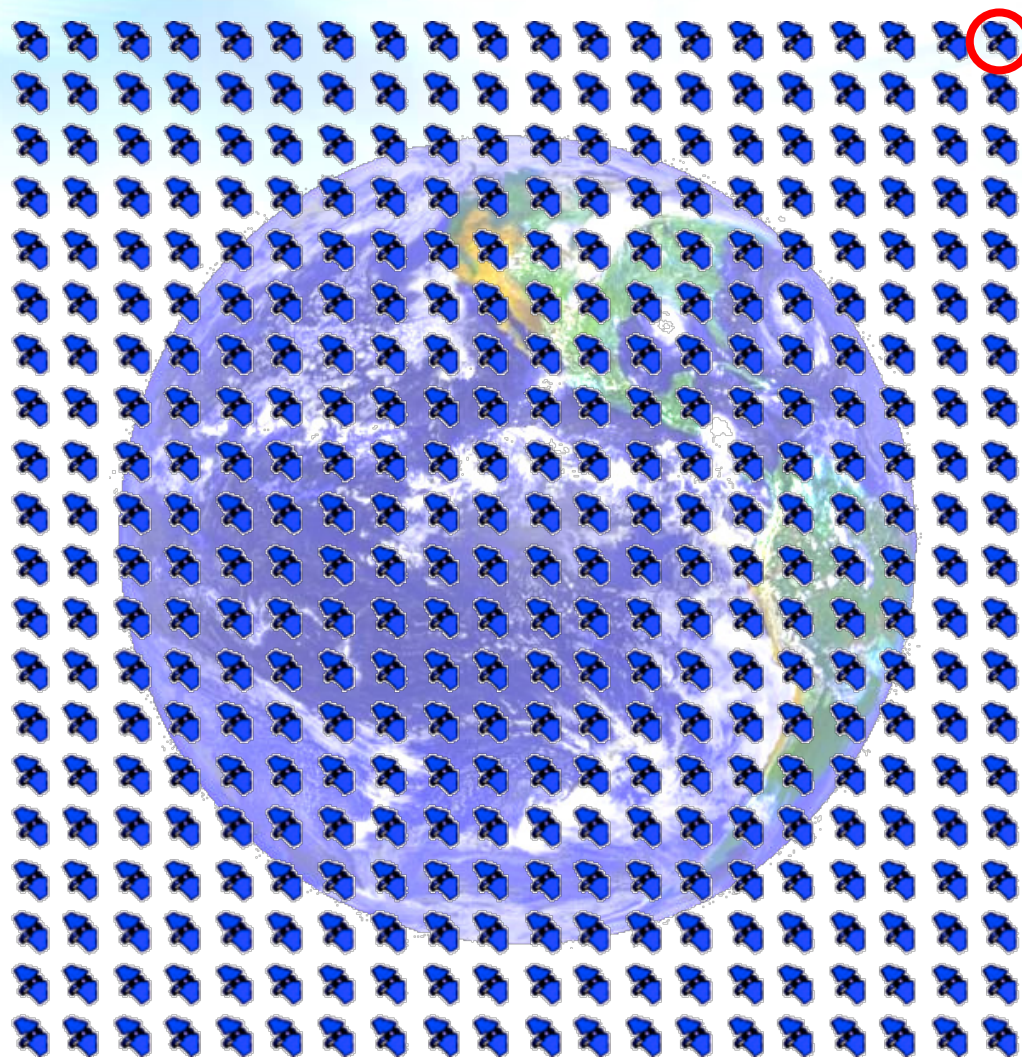


Four weather sensors on two platforms: **\$11.3 billion** life cycle cost

Average cost-to-orbit: **more than \$800 million** per sensor



\$800,000,000 will soon buy:

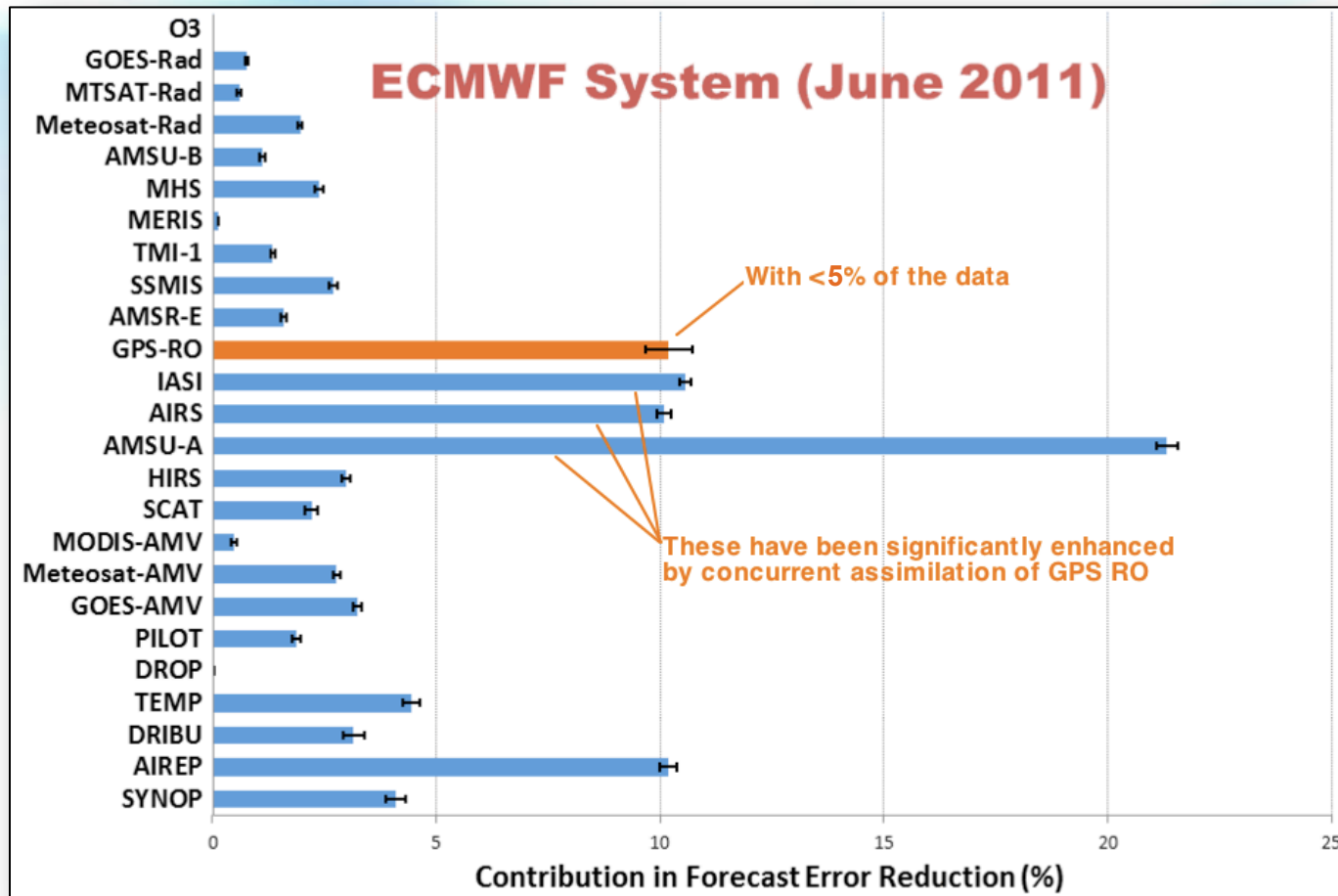


400 RO sats to orbit, **~800,000** profiles/day



Impacts of Measurements on Weather Forecasts

Diverse Measurements Used in Forecasts

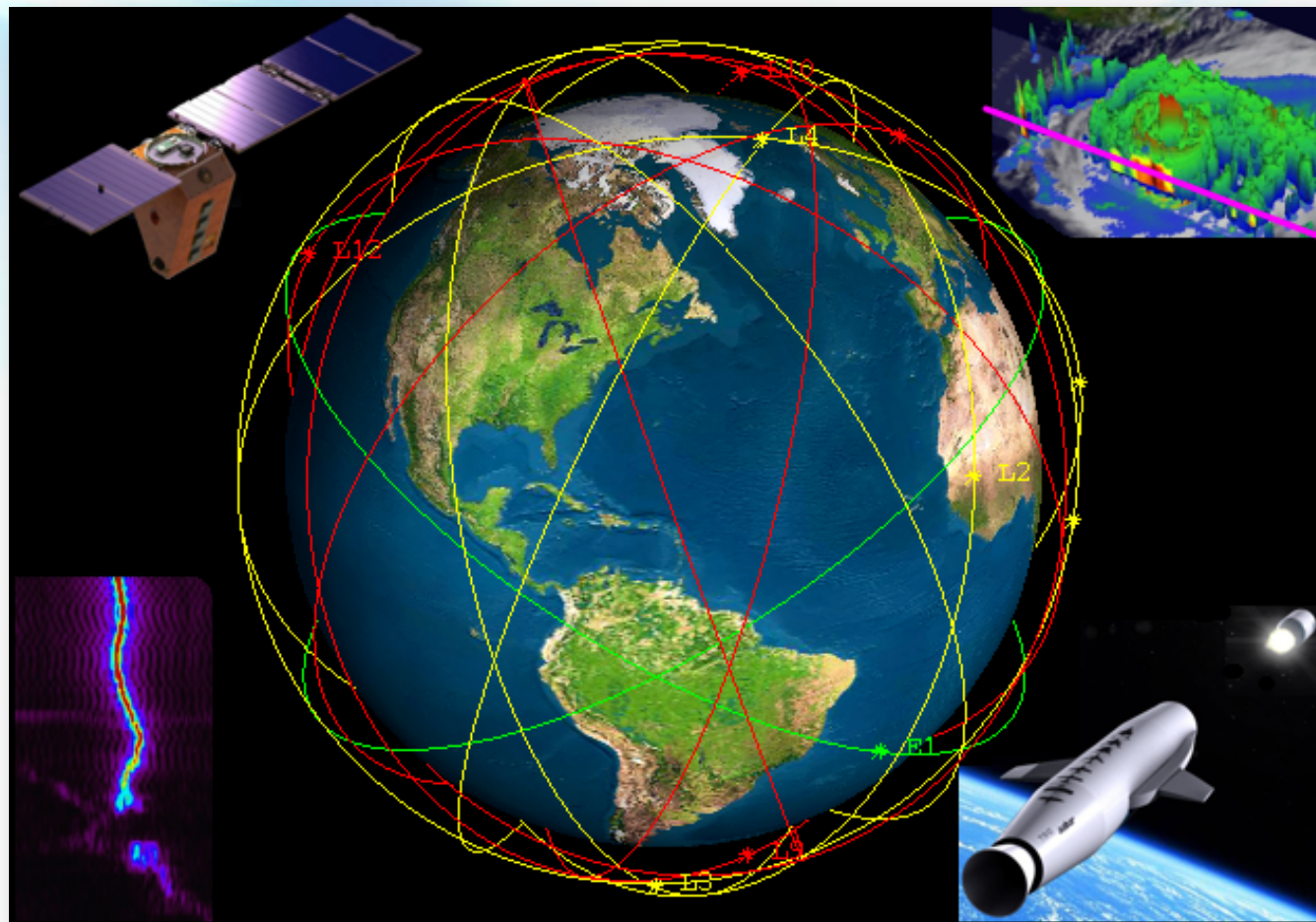


Analysis performed by ECMWF, 2011

At <5% of the observations (and a minute fraction of the cost), RO has a forecast impact comparable to IR (IASI & AIRS) and microwave (AMSU-A). In addition, the RO data, through its calibration effect, improves the IR and microwave results. Without RO included in the forecast, those bars would be smaller.



The CICERO Project – Today's Hype



24 satellites by 2018
100 satellites by 2024?

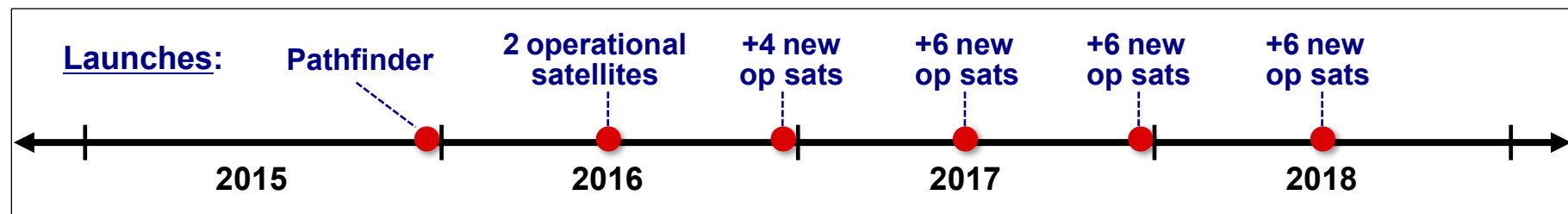
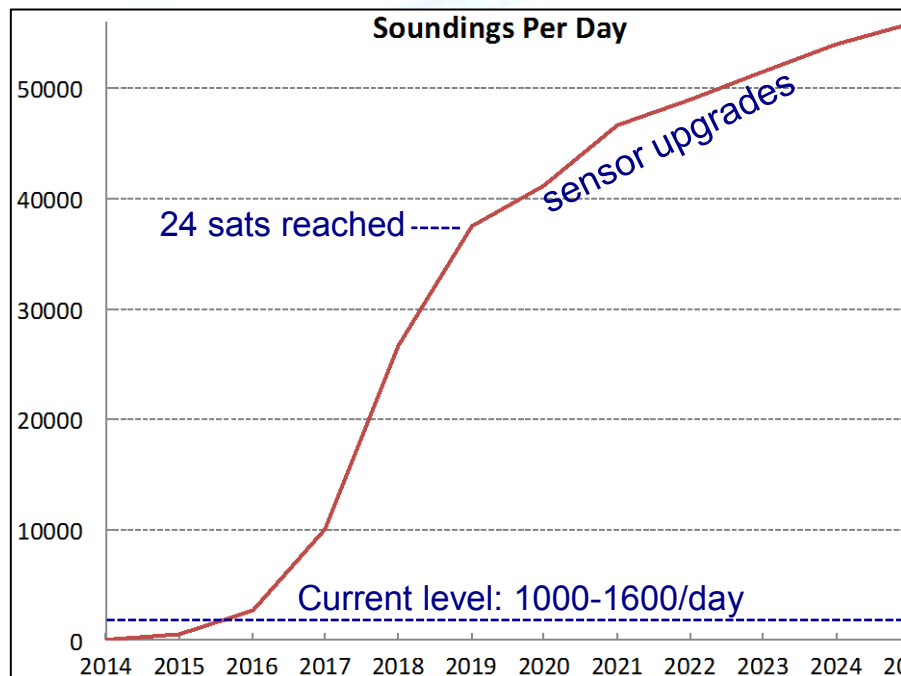
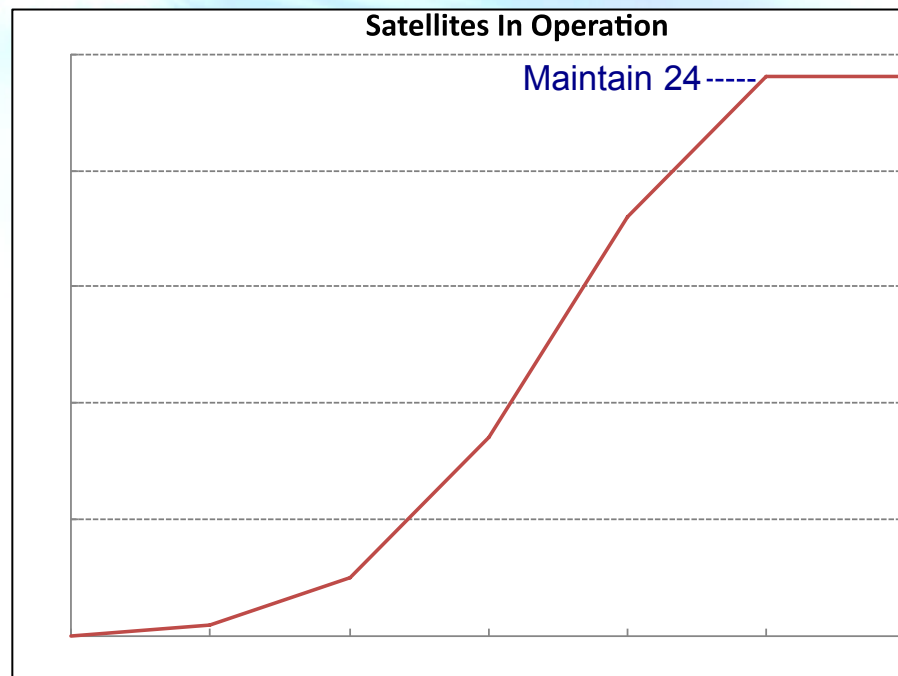


The Instrument: Modified JPL TriG

- Same performance
- Reduced size and power

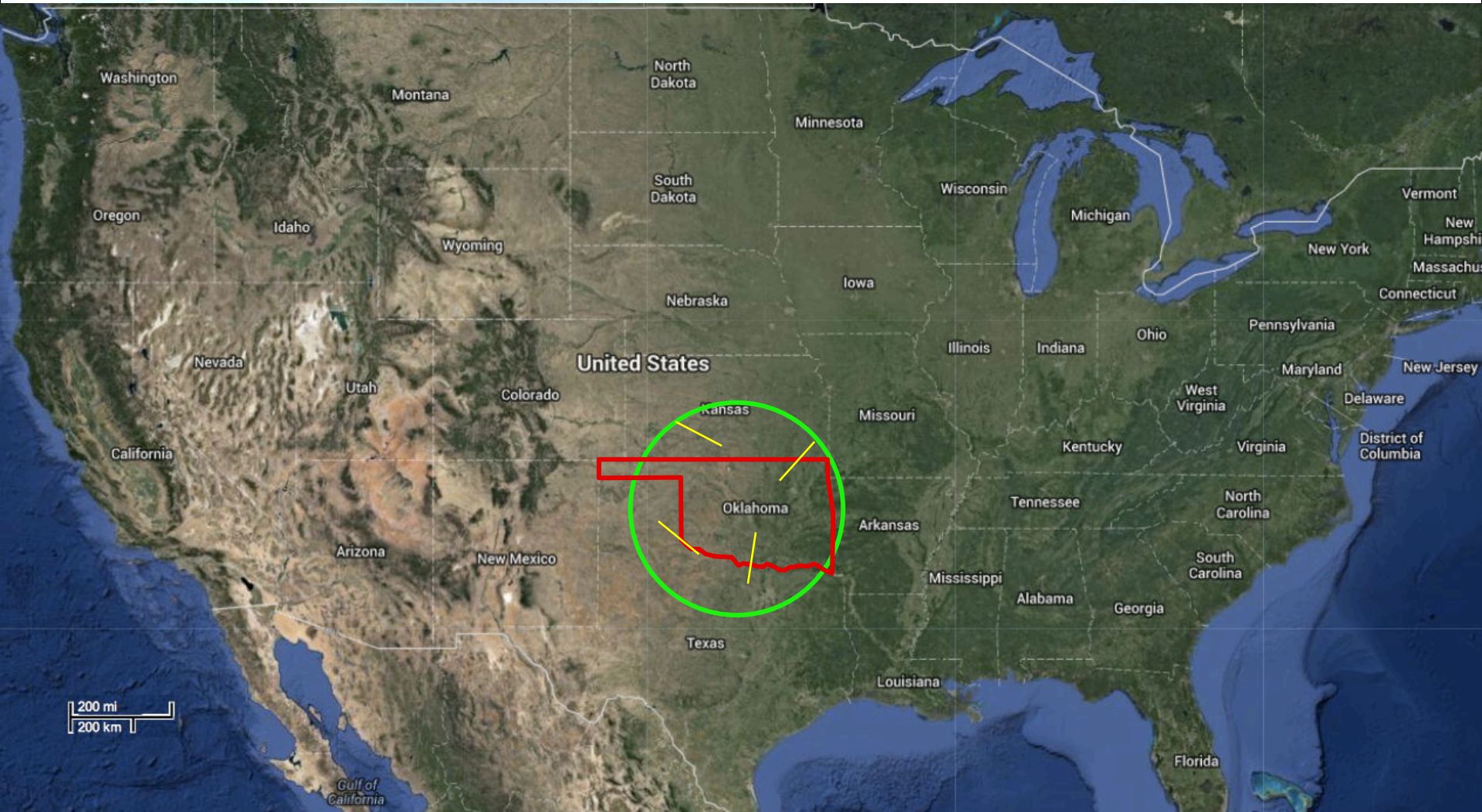


Nominal Deployment Timeline





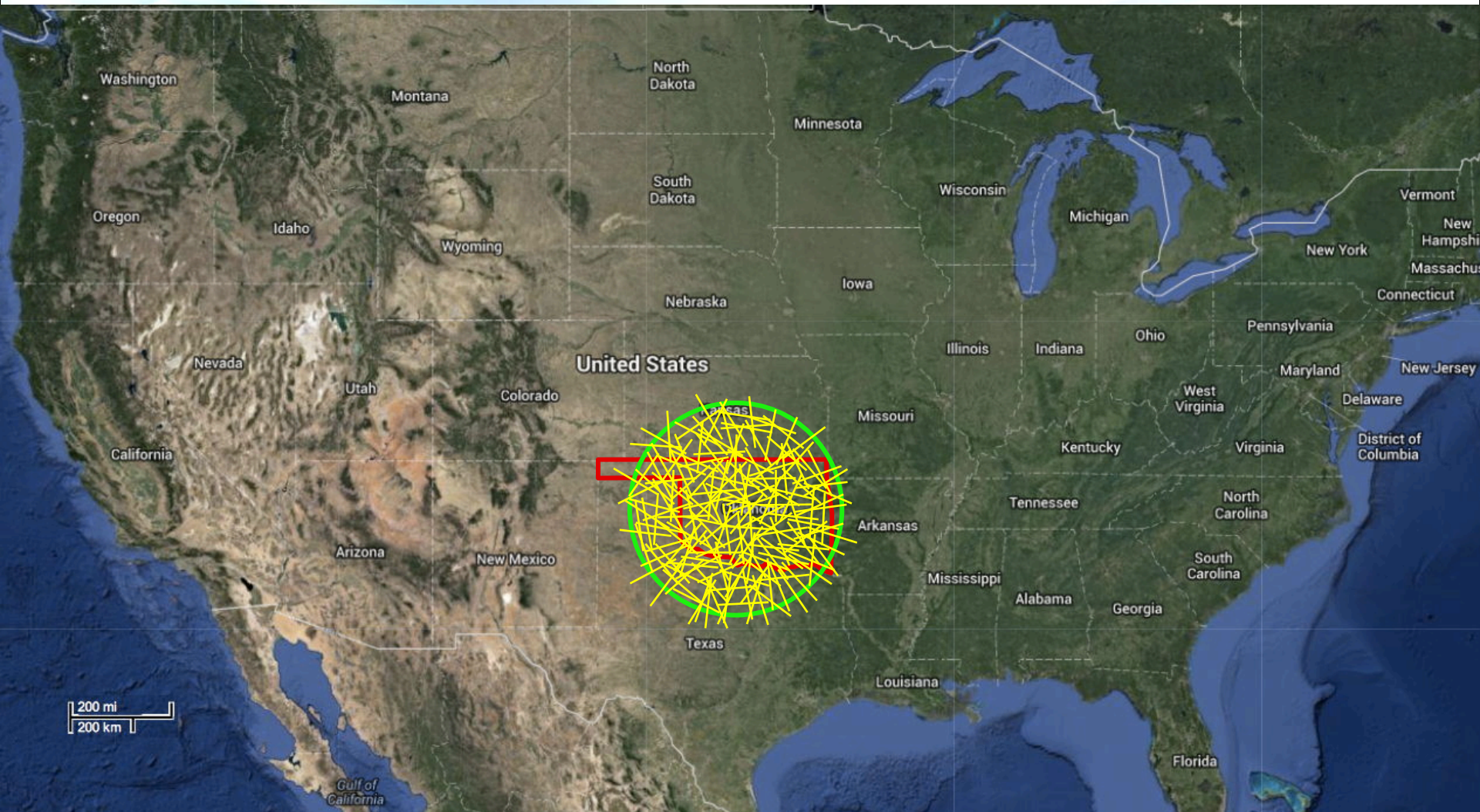
RO Over Oklahoma Today (COSMIC, etc.)



Approximate daily coverage



COSMIC-2 + 24 CICERO satellites



Approximate daily coverage



CICERO Data Policy

- Data will be FREE to all researchers worldwide from day 1
- Data will be FREE to all countries on a trial basis
- Data will be FREE to all countries once a “worldwide license” is fully subscribed



Benefits of This Model

- Will deliver lots of new data quickly
 - minimal cost, spread over many nations
- Eases the agency approval process
 - simpler procurement process
 - zero cost risk to government
- Provides data indefinitely
- Offers built-in technology infusion path
 - launches every few months
- Science community will share oversight



CICERO as a Community Cooperative

Scientists will serve directly:

- As Directors/Officers/Managers
- On the Science Advisory Board
- As research staff
- As technical consultants
- By providing new technologies



What we're trying to do:

Achieve the greatest good with available resources

- Deploy RO sensors in **large** numbers,
- ...as soon as humanly possible,
- ...at the lowest possible cost,
- ...shared by many public users,
- ...with continuous technology infusion,
- ...at **zero** public risk.



Taking Predictions for IROWG-14 (April 2025)

How Many RO Profiles/Day?

- 50,000 ?
- 100,000 ?
- 200,000 ?
- 500,000 ?
- 1,000,000 ?
- 2,500,000 ?
- _____ ?



Questions?