National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Getting the GeoSTAR instrument concept ready for a space mission

Bjorn Lambrigtsen

Todd Gaier, Pekka Kangaslahti, Boon Lim, Alan Tanner, Chris Ruf†

Jet Propulsion Laboratory - California Institute of Technology

† University of Michigan

June 22, 2011- ESTF2011

GeoSTAR timeline

- Concept: NMP/EO-3 (1998-1999)
- Proof-of-concept prototype: IIP-03 (2003-2006)
- PATH mission: NRC Decadal Survey (2007)
- Key technology: IIP-07 (2008-2011)
- Risk reduction: IIP-10 (2011-2014)
- *Venture mission: 2012-2017?*
- *PATH mission: ~202X?*

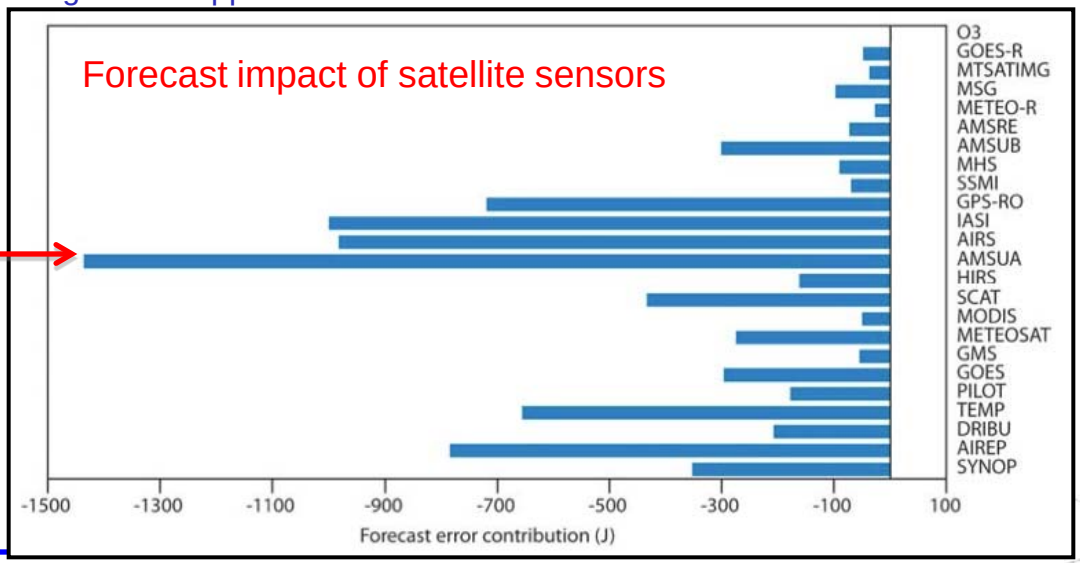
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Why GEO Microwave Sounders?

- **GEO sensors achieve high temporal resolution**
  - LEO: Global coverage, but poor temporal resolution; high spatial res. is easy
  - GEO: High temporal resolution and coverage, but only hemispheric non-polar coverage
  - Requires equivalent measurement capabilities as now in LEO: IR & MW sounders
- **MW sounders measure quantities IR sounders cannot**
  - Meteorologically "interesting" scenes: Full cloud cover; Severe storms & hurricanes
  - Cloud liquid water distribution
  - Precipitation & convection
- **MW sounders complement IR sounders**
  - Complement primary IR sounder with matching MW sounder
  - Microwave provides cloud/"cloud-clearing" information
- **A MW sounder is one of the most desired GEO payloads**
  - High on the list of unmet capabilities
  - Largest number of high-value applications

MW sounders have largest impact

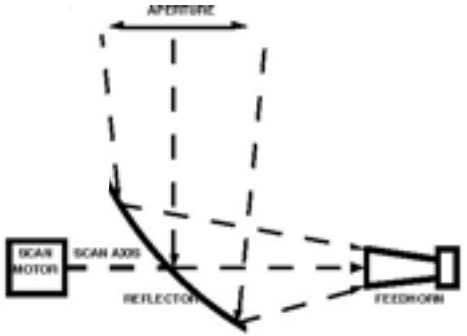


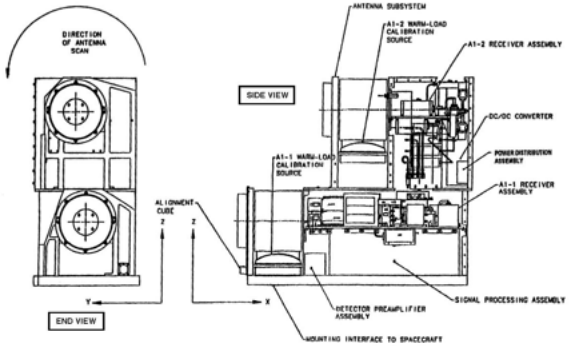
ESTO Earth Science Technology Office

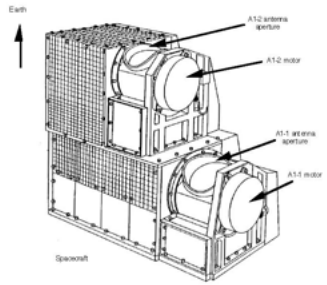
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

The problem: Need large aperture







Low-earth-orbiting MW sounder (AMSU)

The antenna is the key…

- **Antenna size is determined by distance and "spatial resolution"**
- **AMSU antenna is 15 cm dia. ⇒ 50-km resolution from 850 km**
- **GEO orbit is ~36000 km ≈ 42 x 850 km**
- **AMSU-antenna must then be 42 x 15 cm to give 50-km res. from GEO**
- **This is 6.5 meters! Not feasible!**
  This can be reduced somewhat by degrading the antenna efficiency - but still impractical
- **Solution: *Synthesize* large antenna ⇒ GeoSTAR**

ESTO Earth Science Technology Office

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR Development History

NMP EO-3: STAR concept

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		2011	2012

NMP/EO-3: GEO/SAMS

STAR sounder co

ESTO
Earth Science Technology Office

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR Development History

IIP-03: Proof of concept

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

NMP/EO-3: GEO/SAMS

IIP-03: GeoSTAR ptototype

Study

STAR sounder co

STAR c

Compact re

Low-powe

LO phase switching operation

STAR concept and key technologies

Compact receivers

Low-power MMICs

Innovative array layout

LO phase switching system: Ultrastable operation

Partnership with NOAA: Mission study

Spatial resolution	Frequency band	50 GHz	89 GHz	118 GHz	183 GHz
	Antenna element spacing	2.1 cm	1.2 cm	0.9 cm	0.6 cm
150 km	Number of elements	← 3x32 →			
	Arm length	0.7 m	0.4 m	0.3 m	0.2 m
	Power	75 W	75 W	75 W	75 W
	Mass	75 kg	50 kg	45 kg	40 kg
100 km	Number of elements	← 3x48 →			
	Arm length	1.0 m	0.6 m	0.45 m	0.3 m
	Power	115 W	115 W	115 W	115 W
	Mass	100 kg	70 kg	60 kg	50 kg
75 km	Number of elements	← 3x64 →			
	Arm length	1.3 m	0.8 m	0.6 m	0.4 m
	Power	150 W	150 W	150 W	150 W
	Mass	125 kg	90 kg	80 kg	70 kg
50 km	Number of elements	← 3x96 →			
	Arm length	2.0 m	1.1 m	0.85 m	0.6 m
	Power	235 W	235 W	235 W	235 W
	Mass	200 kg	130 kg	115 kg	100 kg
30 km	Number of elements	← 3x160 →			
	Arm length	3.4 m	1.9 m	1.4 m	0.9 m
	Power	400 W	400 W	400 W	400 W
	Mass	300 kg	225 kg	190 kg	150 kg

ESTO Earth Science Technology Office

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR Development History

Calibration & performance assessment

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

NMP/EO-3: GEO/SAMS

IIP-03: GeoSTAR ptototype

Study

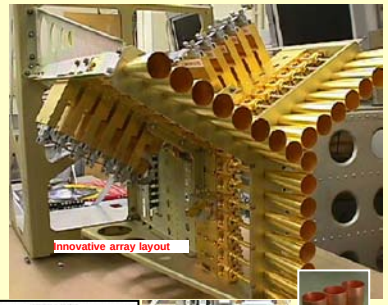
JPL R&TD: GeoSTAR calibration

STAR sounder concept

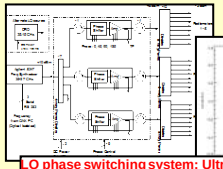
STAR concept and key technologies developed & tested

Compact receivers

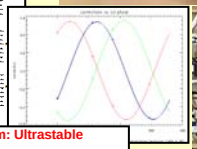
Low-power MMICs



Innovative array layout

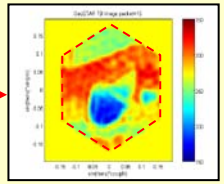


LO phase switching system: Ultrastable operation



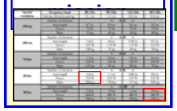
Correlator:
- Efficient
- Redundant
- OK for ASICs

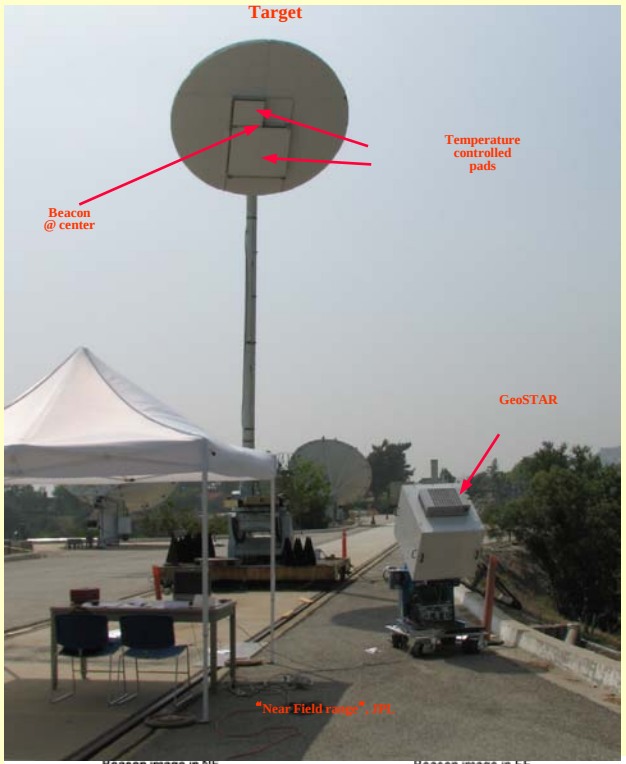
Feedhorns: Low mutual coupling

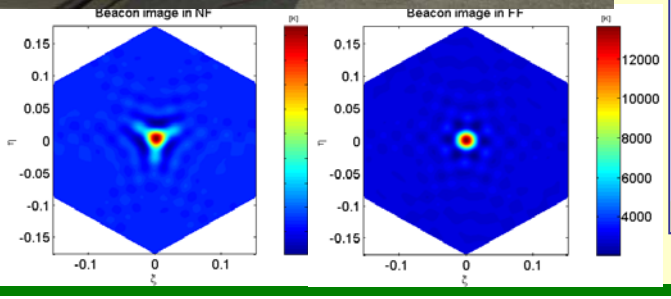


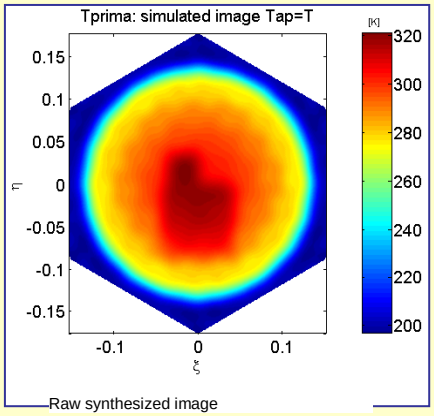
First images at 50 GHz by aperture synthesis

NOAA

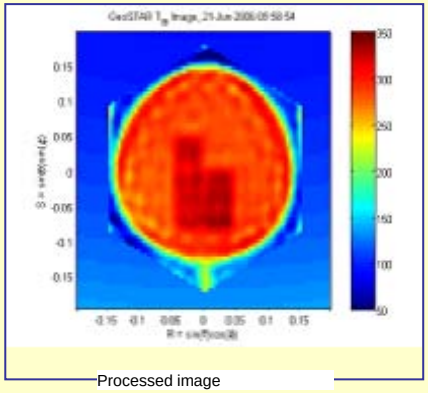








Raw synthesized image



Processed image

Earth Science Technology Office

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

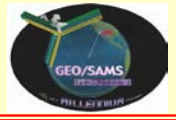
GeoSTAR Development History

ACT-05: 183-GHz technology

1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012

NMP/EO-3: GEO/SAMS

STAR sounder concept



IIP-03: GeoSTAR ptototype

Study

Study

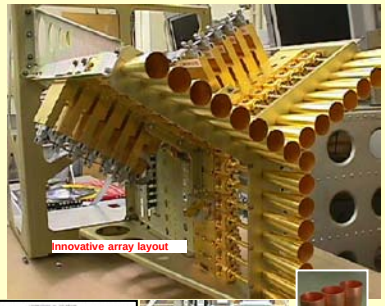
ACT: 183-GHz MMIC development

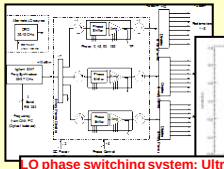
IPP: MMIC development

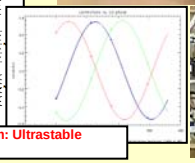
JPL R&TD: GeoST

STAR concept and key technologies developed & tested

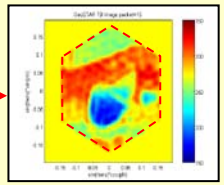
Compact receivers





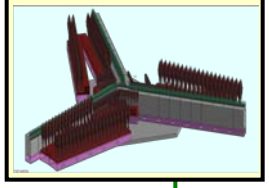


LO phase switching system: Ultrastable operation

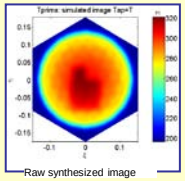


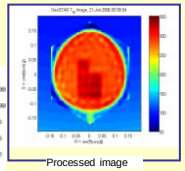
First images at 50 GHz by aperture synthesis

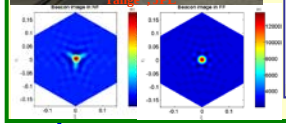
Design innovations



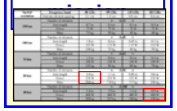
Calibration, perform-ance verification



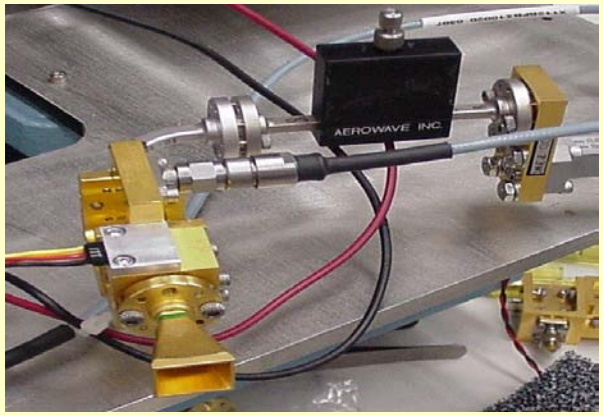


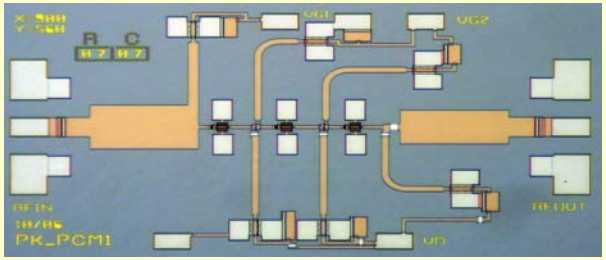


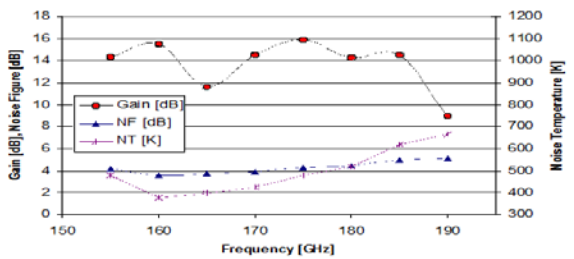
NOAA



Breakthrough MMIC performance



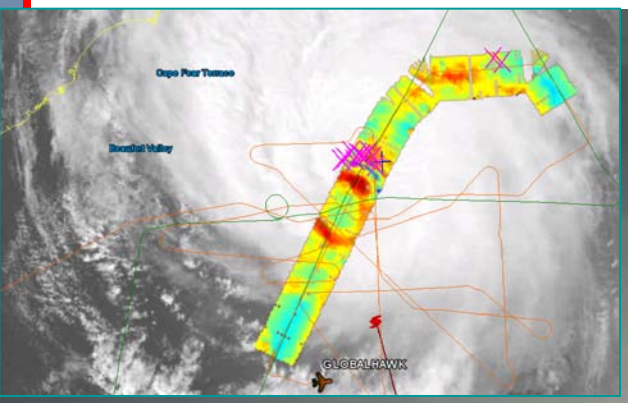




National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Sidebar:



Hurricane Earl, September 2, 2010

National Aeronautics and Space Administration

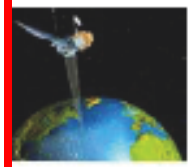
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR Development History

Decadal survey: PATH mission

PATH applications

Weather forecasting	All-weather soundings, in cloudy and stormy scenes Soundings @<50/25 km every 15-30 minutes (continuous) Synoptic rapid-update soundings Forecast error detection; 4DVAR applications
Hurricane & severe-storm diagnostics	Location, intensity & vertical structure of deep convection NRT atmospheric instability; tornado precursor detection Intensification/weakening in NRT, frequently sampled Measure all H_2O phases: vapor, liquid, ice, rain/snow Operational analysis, forecast verification Improved model microphysics
Rain	Full hemisphere @ ≤ 25 km every 15 minutes Directly measure storm and diurnal total rainfall: predict flooding events Snowfall, light rain, intense convective precipitation
Tropospheric wind profiling	1000-300 mb; very high temp.res.; in & below clouds Air quality applications (pollution transport)
Climate research	Stable & continuous MW observations Long term trends in T & q and storm statistics Fully resolved diurnal cycle ENSO; monsoon; tropical moisture flow into the US "Science continuity": GeoSTAR ≈ AMSU



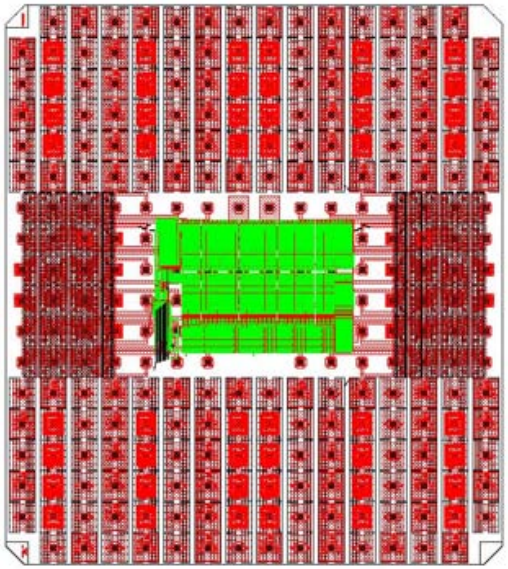
ESTO Earth Science Technology Office

National Aeronautics and Space Administration

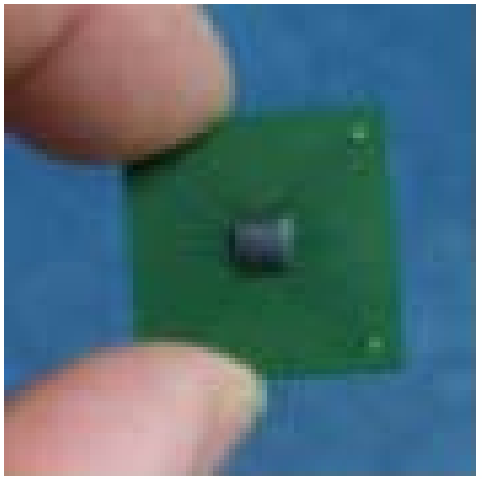
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

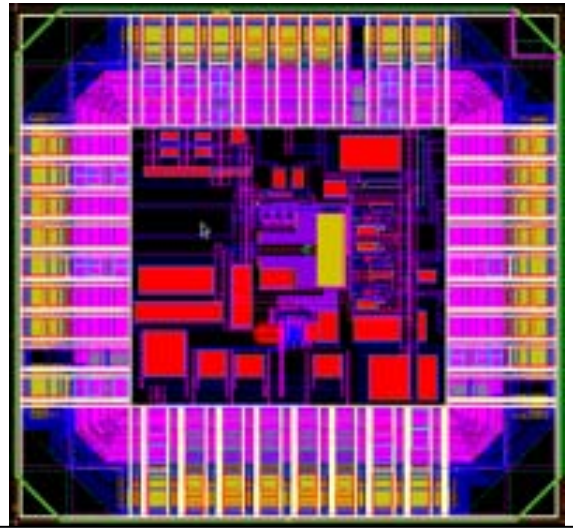
GeoSTAR Development History

ASICs (small demo chips)

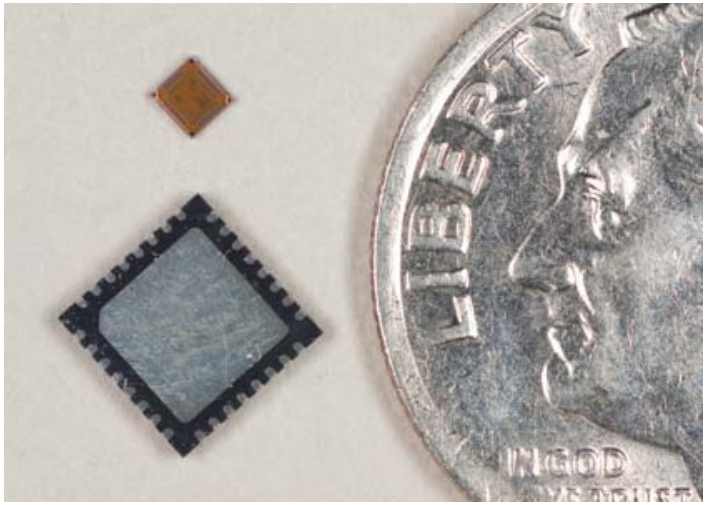


Correlator chip





ADC chip

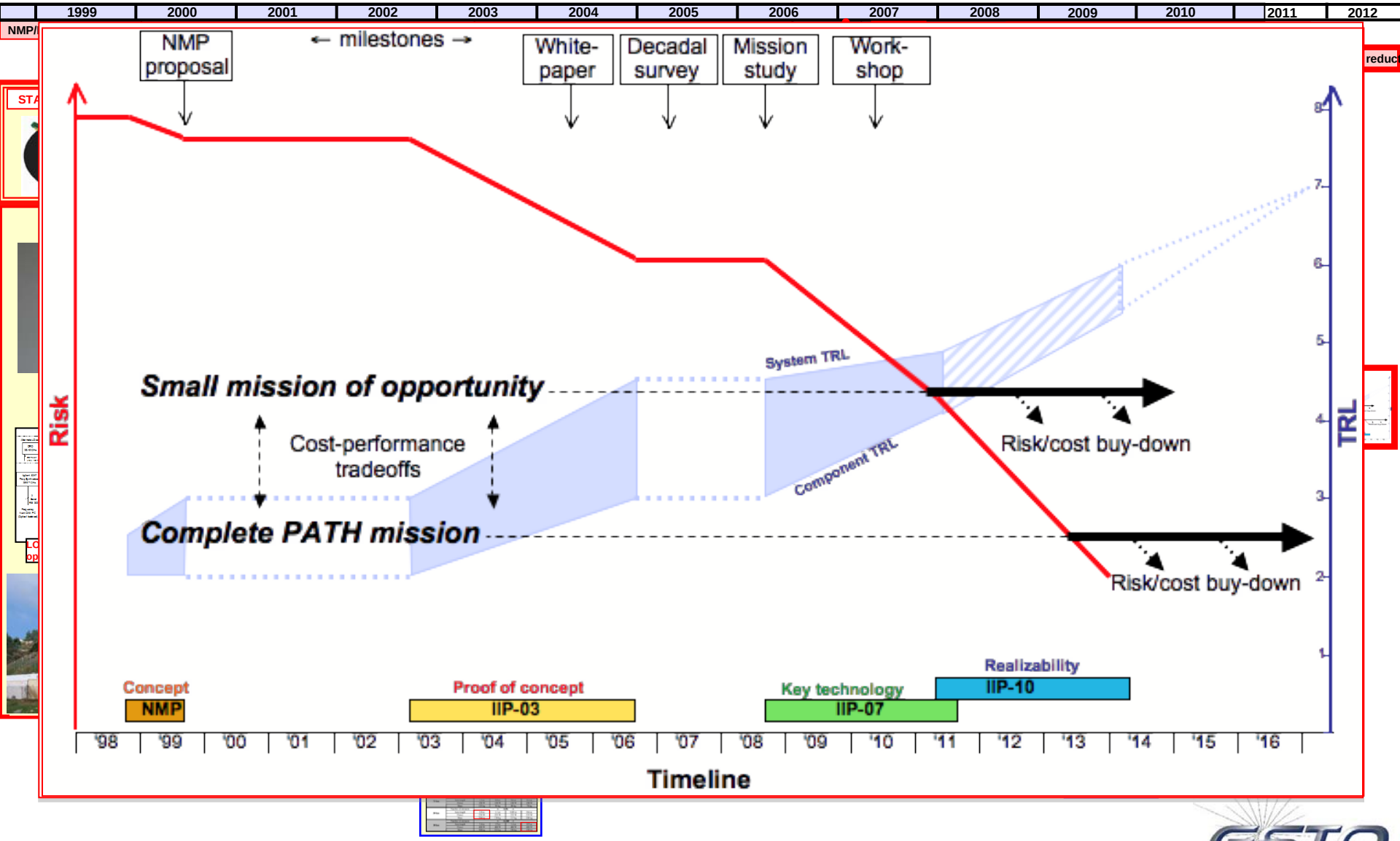


National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR Development History

PATH risk reduction: IIP-10



ESTO
Earth Science Technology Office

Summary

We are approaching readiness for space mission

- STAR concept demonstrated in IIP-03
- Key technologies developed in IIP-07
- Ready for PATH mission after IIP-10
  - Can start development ~2015 → launch ~2020
- ***Ready for Venture-class mission now***
  - Timeline: Start development ~2012 → Launch ~2016
  - Objective: PATH science subset demonstrator
  - Instrument: "GeoSTAR-lite" – all key technologies @ TRL 6
    - Correlator baseline: FPGA (TRL 6) – meets minimum science requirements