GEO-CAPE Mission Implementation Concepts

2nd GEO-CAPE Community Workshop

May 11, 2011

Jay Al-Saadi, Steve Ambrose, Richard Key, Doreen Neil

GEO-CAPE Mission Background

- Decadal Survey GEO-CAPE mission and payload concept

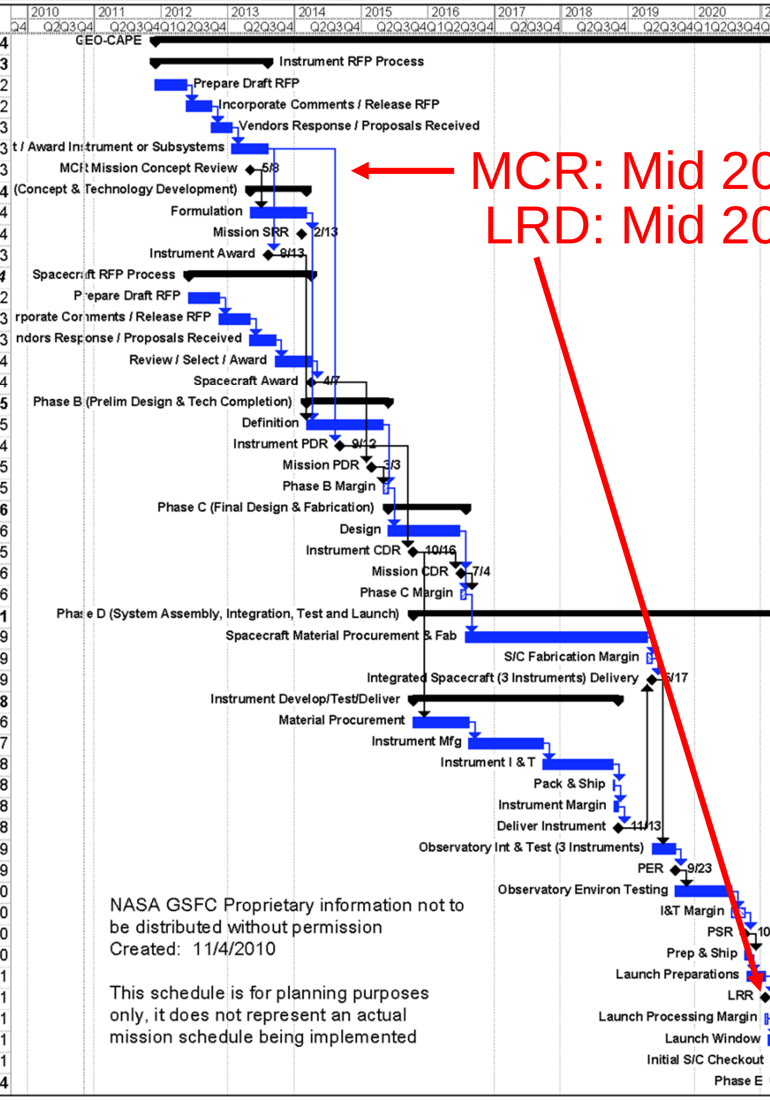
  GEO-CAPE consists of three instruments in geosynchronous Earth orbit near 80°W longitude: a UV-visible-near-IR wide-area imaging spectrometer (7-km nadir pixel) capable of mapping North and South America from 45°S to 50°N at about hourly intervals, a steerable high-spatial-resolution (250 m) event-imaging spectrometer with a 300-km field of view, and an IR correlation radiometer for CO mapping over a field consistent with the wide-area spectrometer.

- Implications of the Decadal Survey GEO-CAPE mission concept
  - GEO-CAPE would be a "dedicated NASA only mission"
  - All instrumentation would fly on the same spacecraft
  - Ocean color measurements need companion atmospheric composition measurements (O_3, NO_2) for atmospheric correction

- A dedicated NASA only GEO-CAPE mission concept as described in the Decadal Survey was studied in 2010 using a planning payload representative of the instrumentation needed for GEO-CAPE

Dedicated GEO-CAPE Mission Schedule

ID	Task Name	Duration	Start	Finish
1	**GEO-CAPE**	**3262 days**	**Wed 12/7/11**	**Fri 5/31/24**
2	***Instrument RFP Process***	**440 days**	**Wed 12/7/11**	**Mon 8/12/13**
3	Prepare Draft RFP	120 days	Wed 12/7/11	Tue 5/22/12
4	Incorporate Comments / Release RFP	100 days	Wed 5/23/12	Mon 10/8/12
5	Vendors Response / Proposals Received	80 days	Tue 10/9/12	Mon 1/28/13
6	*Review / Select / Award Instrument or Subsysten*	140 days	Tue 1/29/13	Mon 8/12/13
7	MCR Mission Concept Review	1 day	Wed 5/8/13	Wed 5/8/13
8	**Phase A (Concept & Technology Development)**	**220 days**	**Thu 5/9/13**	**Wed 3/12/14**
9	Formulation	220 days	Thu 5/9/13	Wed 3/12/14
10	Mission SRR	1 day	Thu 2/13/14	Thu 2/13/14
11	Instrument Award	1 day	Tue 8/13/13	Tue 8/13/13
12	***Spacecraft RFP Process***	***480 days***	***Wed 6/6/12***	***Mon 4/7/14***
13	Prepare Draft RFP	120 days	Wed 6/6/12	Mon 11/19/12
14	Incorporate Comments / Release RFP	120 days	Tue 11/20/12	Mon 5/6/13
15	Vendors Response / Proposals Received	100 days	Tue 5/7/13	Mon 9/23/13
16	Review / Select / Award	140 days	Tue 9/24/13	Mon 4/7/14
17	*Spacecraft Award*	0 days	Mon 4/7/14	Mon 4/7/14
18	**Phase B (Prelim Design & Tech Completion)**	**320 days**	**Thu 3/13/14**	**Wed 6/3/15**
19	Definition	300 days	Thu 3/13/14	Wed 5/6/15
20	Instrument PDR	1 day	Fri 9/12/14	Fri 9/12/14
21	Mission PDR	2 days	Mon 3/2/15	Tue 3/3/15
22	***Phase B Margin***	20 days	Thu 5/7/15	Wed 6/3/15
23	**Phase C (Final Design & Fabrication)**	**305 days**	**Thu 6/4/15**	**Mon 8/1/16**
24	Design	280 days	Thu 6/4/15	Mon 6/27/16
25	Instrument CDR	2 days	Thu 10/15/15	Fri 10/16/15
26	Mission CDR	5 days	Tue 6/28/16	Mon 7/4/16
27	***Phase C Margin***	20 days	Tue 7/5/16	Mon 8/1/16
28	**Phase D (System Assembly, Integration, Test anc**	**1420 days**	**Mon 10/19/15**	**Tue 3/23/21**
29	Spacecraft Material Procurement & Fab	710 days	Tue 8/2/16	Fri 4/19/19
30	***S/C Fabrication Margin***	20 days	Mon 4/22/19	Fri 5/17/19
31	Integrated Spacecraft (3 Instruments) Delivery	0 days	Fri 5/17/19	Fri 5/17/19
32	**Instrument Develop/Test/Deliver**	**805 days**	**Mon 10/19/15**	**Tue 11/13/18**
33	Material Procurement	220 days	Mon 10/19/15	Wed 8/17/16
34	Instrument Mfg	292 days	Thu 8/18/16	Thu 9/28/17
35	Instrument I & T	273 days	Fri 9/29/17	Tue 10/16/18
36	Pack & Ship	5 days	Wed 10/17/18	Tue 10/23/18
37	***Instrument Margin***	15 days	Wed 10/24/18	Tue 11/13/18
38	Deliver Instrument	0 days	Tue 11/13/18	Tue 11/13/18
39	Observatory Int & Test (3 Instruments)	90 days	Mon 5/20/19	Fri 9/20/19
40	PER	1 day	Mon 9/23/19	Mon 9/23/19
41	Observatory Environ Testing	220 days	Tue 9/24/19	Mon 7/27/20
42	***I&T Margin***	51 days	Tue 7/28/20	Tue 10/6/20
43	PSR	1 day	Wed 10/7/20	Wed 10/7/20
44	Prep & Ship	10 days	Thu 10/8/20	Wed 10/21/20
45	Launch Preparations	70 days	Thu 10/22/20	Wed 1/27/21
46	LRR	0 days	Wed 1/27/21	Wed 1/27/21
47	***Launch Processing Margin***	10 days	Thu 1/28/21	Wed 2/10/21
48	Launch Window	15 days	Thu 2/11/21	Wed 3/3/21
49	Initial S/C Checkout	14 days	Thu 3/4/21	Tue 3/23/21
50	**Phase E**	**833 days**	**Wed 3/24/21**	**Fri 5/31/24**



MCR: Mid 2013
LRD: Mid 2021

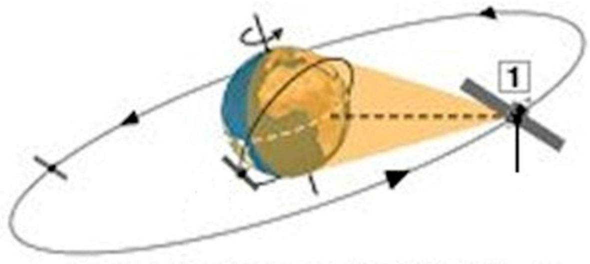
Project: GEO CAPE
Date: Thu 11/4/10

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

8 years of development, 3 years of operations, life-cycle cost ~$1.5B

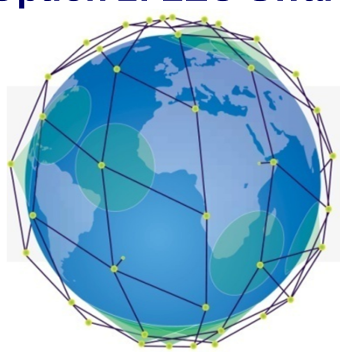
Mission Architecture Concepts for Time-Resolved Science

Option 1: NASA GEO spacecraft



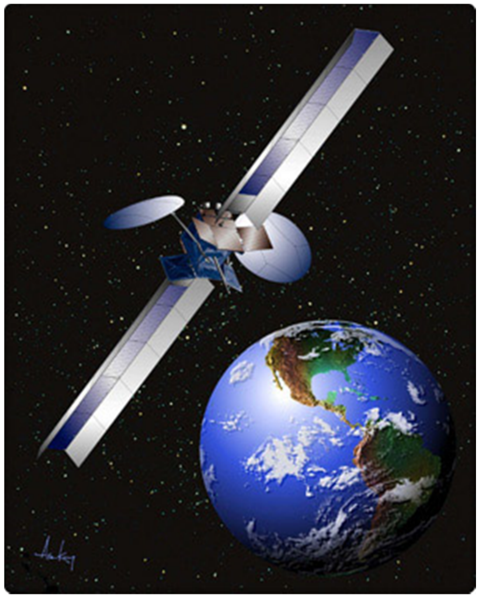
Dedicated, long life GEO spacecraft
Orbit 35,786 km stationary orbit above Earth
Examples: GOES, TDRSS

Option 2: LEO Swarm



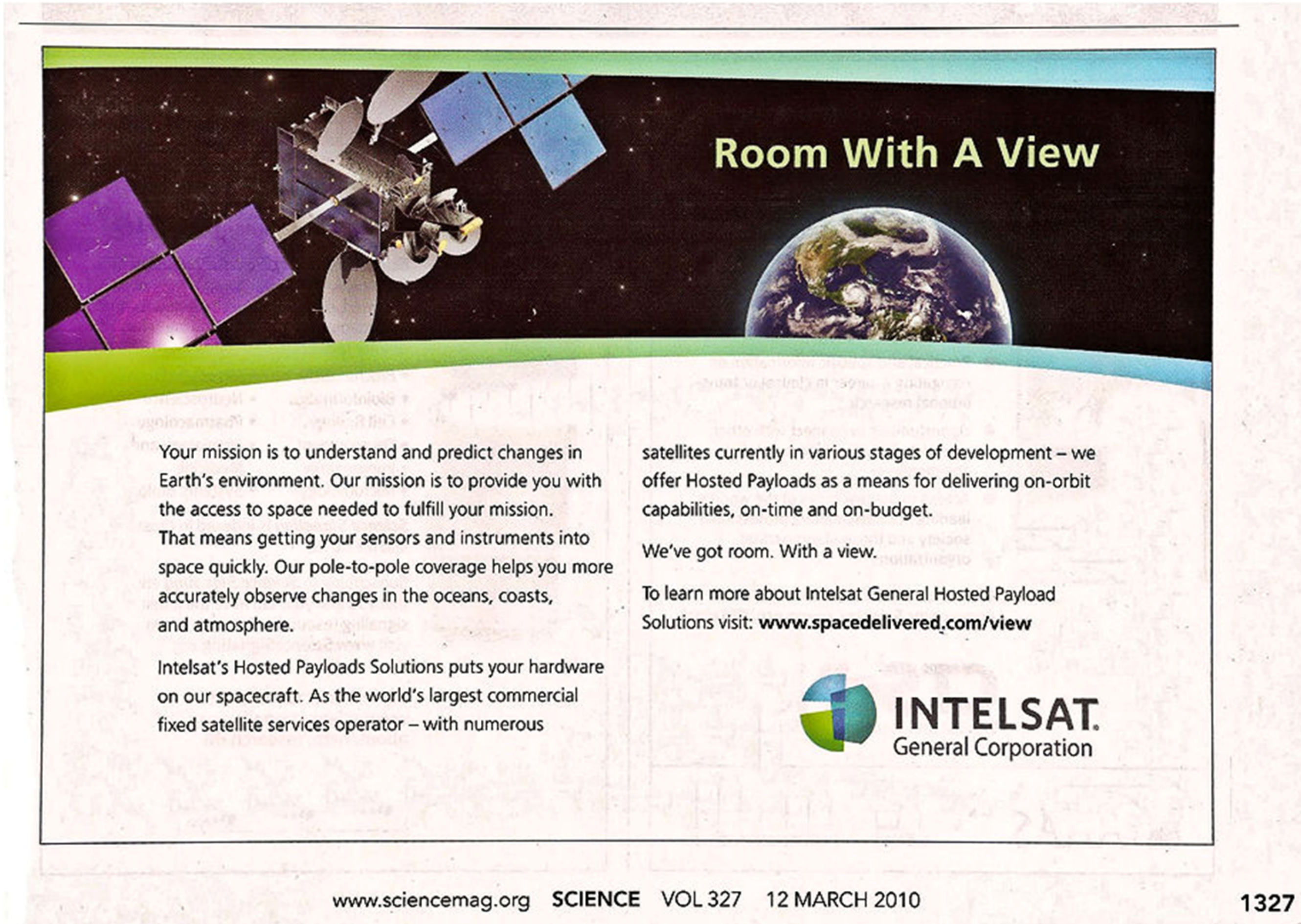
Multiple inter-calibrated copies
6-10 spacecraft and launches to Leo
Examples: IRIDIUM, GPS

Option 3: NASA payload hosted on commercial GEO spacecraft



Frequent launches to GEO
Excess capacity (mass and power)
Examples: FAA's WAAS, Air Force CHIRP

Hosted Payload Invitation

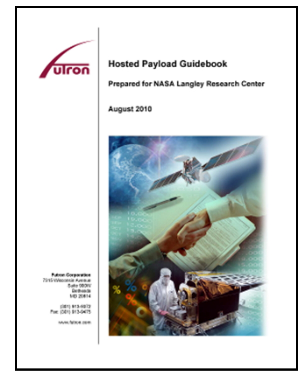


Industry has recently formed the Hosted Payload Alliance to advance the use of hosted payloads on commercial satellites and to create an open dialogue between government and industry on the issues affecting hosted payloads, at both the policy and program level

Hosted Payload Concept Background

- Most geo commercial communications satellites launch with unused space on the nadir deck that can accommodate secondary “hosted payloads”
- An interagency working group is establishing the framework for government payloads to be hosted on commercial satellites and GEO-CAPE mission designers are members of that working group
- NASA has studied Geo HPL mission concepts for many years and has just published an authoritative hosted payload guidebook
- There is a track record of hosted payloads which provides a basis for estimating cost and complexity

Typical communications payloads have large deployed reflectors on both east and west sides



FAA Wide Area Augmentation System (WAAS)

Anik f1-R

Galaxy 15

LMC, Telesat, Intelsat

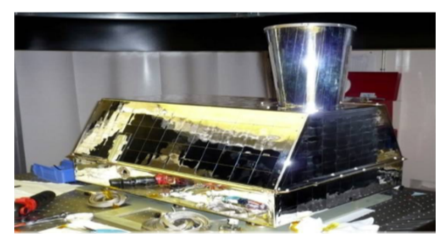
DOD
Internet Router In Space (IRIS)

Intelsat, Loral

Australian Defense Force UHF

Intelsat, Boeing

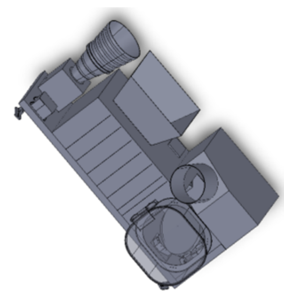
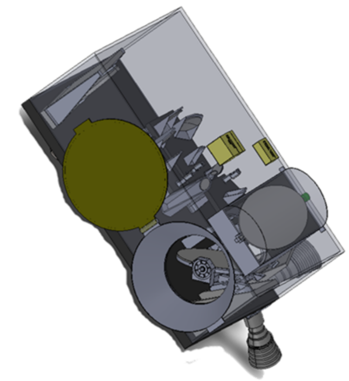
Air Force Commercially Hosted Infrared Payload (CHIRP)



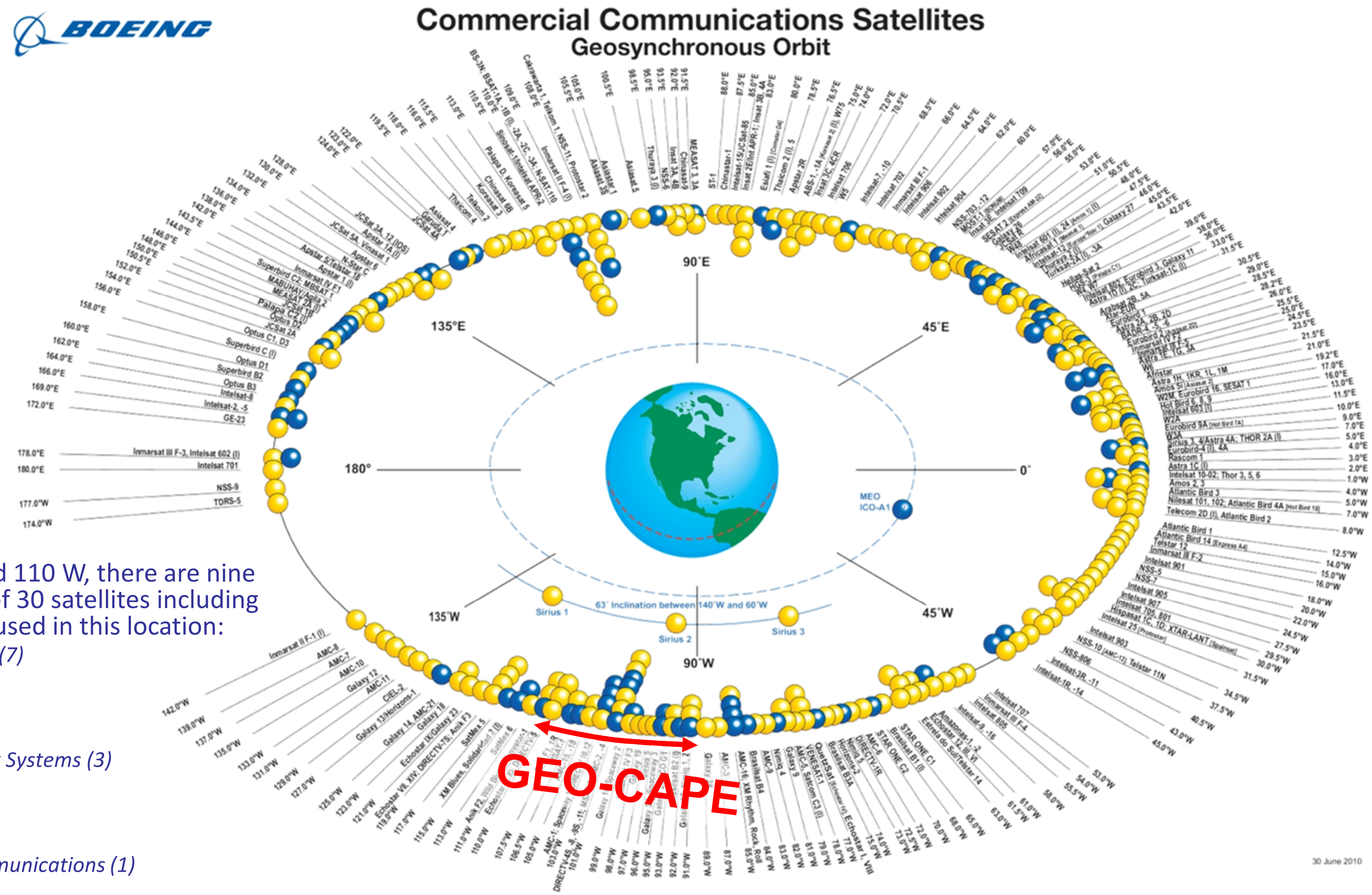
SES, Orbital

GEO-CAPE Planning Payload

The GEO-CAPE planning payload is representative of the instrumentation that could accomplish the science measurements defined in the STMs

	Small	Medium	Large
GEO-CAPE Notional Planning Payload Instrumentation	 CISR	 GeoMAC	 CEDI
Science	Atmospheric Composition		Coastal Ecosystems
Instrument Concept	Gas-Filter Correlation Radiometer	UV-Vis Spectrometer	UV-Vis-NIR Spectrometer
Spectral Range (μm)	2.3 and 4.67	0.30 to 0.48	0.34 to 0.90 1.225 to 2.160
Size: L x W x H (m)	0.75 x 0.4 x 0.5	1.7 x 0.8 x 0.9	2.1 x 0.95 x 2.8
CBE Mass (kg)	45	140	621
CBE Power (W)	120	233	392
Data Rate (Mbps)	40	16.4	88.4

Geostationary Orbit Opportunities

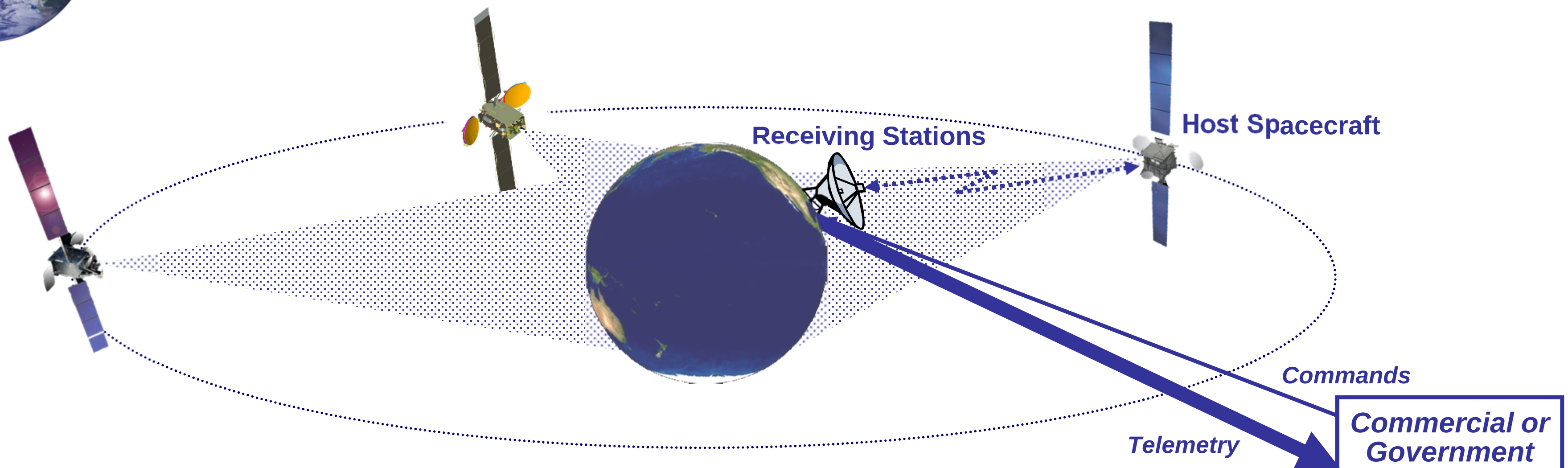


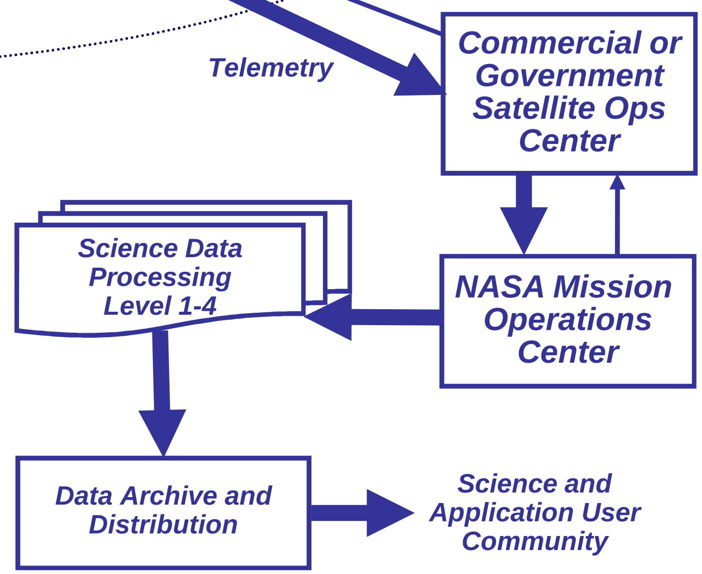
Between 90 W and 110 W, there are nine owner operators of 30 satellites including older models still used in this location:

- *Direct TV Group (7)*
- *AGS (5)*
- *Intelsat (5)*
- *Telesat (4)*
- *Hughes Network Systems (3)*
- *Echostar (2)*
- *SkyTerra (2)*
- *Inmarsat (1)*
- *ICO Global Communications (1)*

As older satellites are replaced there will be many hosted payload opportunities in the orbit locations most useful for GEO-CAPE observations (85W to 110W)

Hosted Payload Concept of Operations





- Geostationary orbit provides the option for continuous downlink because the satellite remains in the same fixed location over the ground station for the life of the mission
  - *Minimal data latency could support near real time applications such as chemical weather forecasting*
- The hosted payload approach provides the option to purchase telemetry services from the satellite operator (if it is a comsat)
  - *Continuous direct data transfer from instrument to host comsat transponders (bent pipe downlink)*
- NASA operates science processing, archive, and distribution

GEO-CAPE Hosted Payload Study

- Discussions are on-going with government host missions (TDRSS and GOES)

- GEO-CAPE Mission Design Group conducted a Commercial Hosted Payload (HPL) mission design lab (MDL) at GSFC in August 2010
  - Assessed compatibility of planning payload instruments with geo spacecraft from the four domestic geo spacecraft manufacturers
  - Small, medium and large instruments were studied with each spacecraft manufacturer
  - No technical showstoppers were found for hosted payloads
    - Found that the bigger the payload the more it costs to host that payload
    - If the payload gets to large it becomes the “primary” payload
    - Instruments designed to have a low impact on the host spacecraft can be accommodated on more spacecraft / will have more flight opportunities

  - Hosted payloads are attractive to the owner/operators as a source of revenues for excess capacities (e.g. spare transponders, power, space)

HPL Implementation Study Findings

- Future commercial mission opportunities could enable GEO-CAPE instruments to operate as part of an international geo constellation
- A GEO-CAPE hosted payload mission implementation could cost substantially less than a dedicated mission or commercial bus purchase
  - Dedicated mission initial cost estimate ≈ $1.5B (FY11 $)
  - Hosted payload implementation initial cost estimate ≈ $1.1B (FY11 $)
    - Small payload (CISR) ≈ $147M (FY11 $)
    - Medium payload (GeoMAC (UV-Vis)) ≈ $ 298M (FY11 $)
    - Large payload (CEDI) ≈ $ 720M (FY11 $)
- Significant mission implementation risk reduction is achieved by hosting instruments separately on multiple platforms
  - The impact of a GLORY like failure would be the cost of building a copy of the instrument rather than the cost of replicating the entire mission (i.e. spacecraft, launch vehicle, etc.)

Hosted Payload Mission Risk Reduction

- Technical Risks
  - Interference from operations of other payloads
  - Interfaces with host spacecraft
  - Science measurements from geostationary orbit

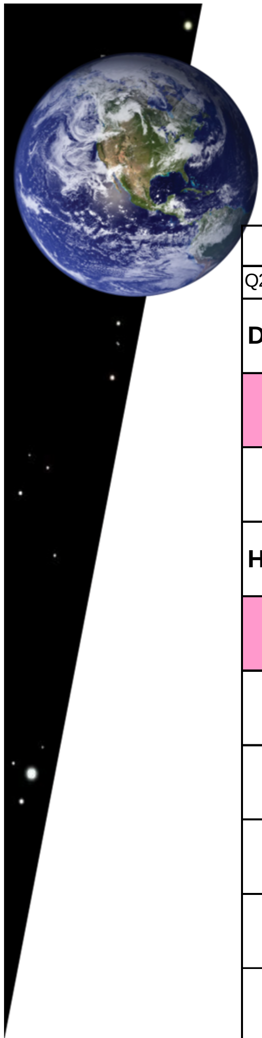
- Programmatic Risks (Liabilities, Rights, Responsibilities)
  - Launch delay or failure
  - Host or payload development delay or failure
  - Host or payload operational full / partial loss or failure
  - Primary mission precedence
  - Orbital slot placement/maintenance (or changes)

- GEO-CAPE programmatic risk will be reduced by using the framework for hosting government payloads on commercial satellites established by the interagency hosted payload working group

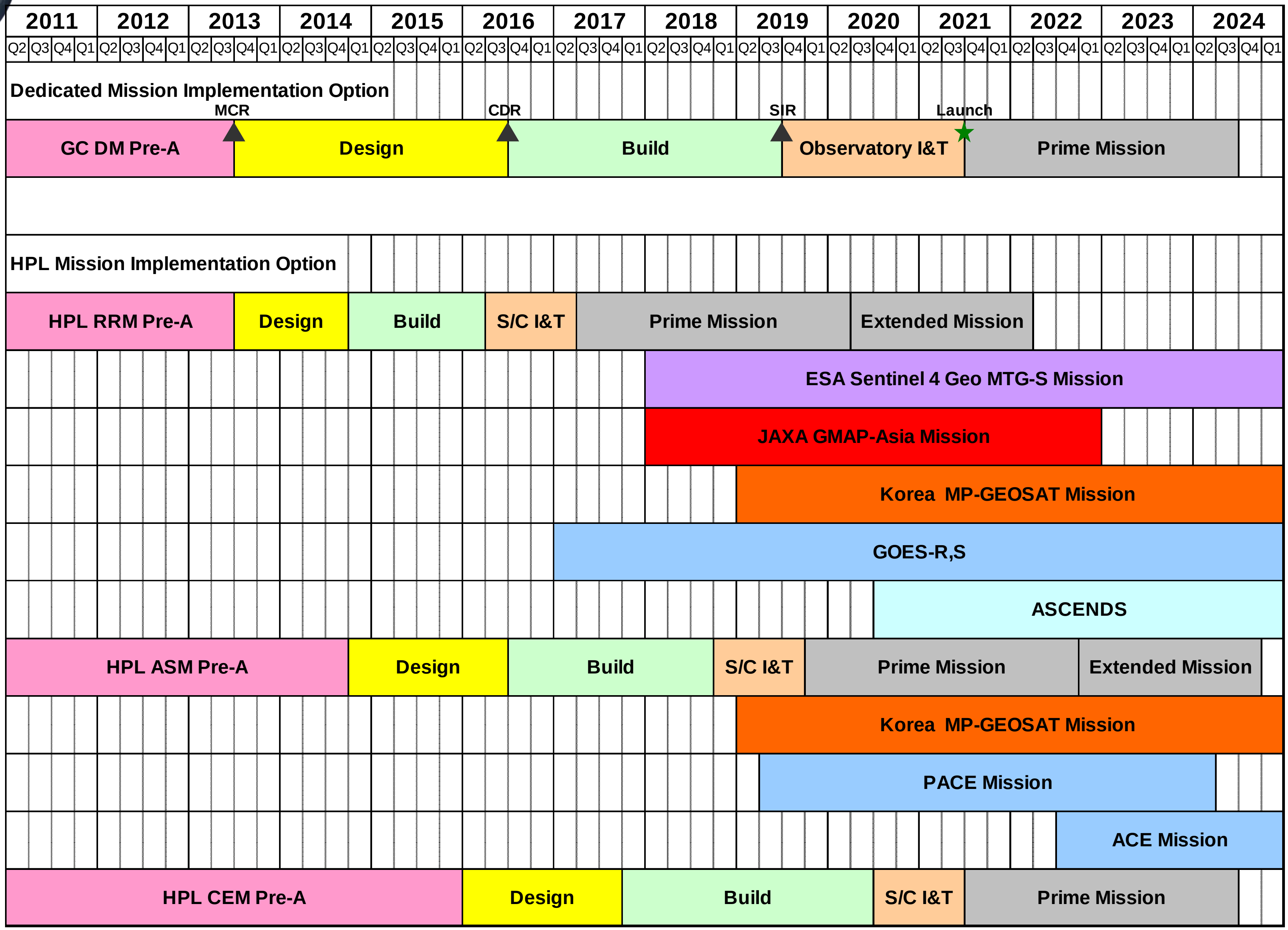
A small simple pathfinder HPL risk reduction mission could be the first step of a phased implementation for the GEO-CAPE mission

Phased Implementation Concept

- Launching science instrumentation in phases can accomplish GEO-CAPE science objectives at lower risk than a single launch while staying within the same overall schedule from MCR to LRD
  - Risk Reduction Mission (RRM) with a small instrument
    - Pathfinder for HPL technical & programmatic risks / mitigations
    - Demonstrate the HPL approach is a viable implementation option
    - Demonstrate GEO-CAPE measurements are possible from geo
    - Demonstrate combination of Leo and Geo atmospheric science data
  - Atmospheric Science Mission (ASM) with a medium size instrument
    - Incorporate lessons learned from risk reduction mission
    - Obtain routine systematic atmospheric composition measurements
    - Operate as part of international atmospheric science constellation
    - Establish measurements / data to support ocean color retrievals
  - Coastal Ecosystem Science Mission (CEM) with a large size instrument
    - Launch when instrument accommodation is viable (size, mass, etc.)
    - Utilize measurements / data from atmospheric composition mission
    - Obtain episodic targeted coastal ocean ecosystems science measurements
    - Demonstrate combination of Leo and Geo ocean science data
- Each phase could be developed as funding becomes available



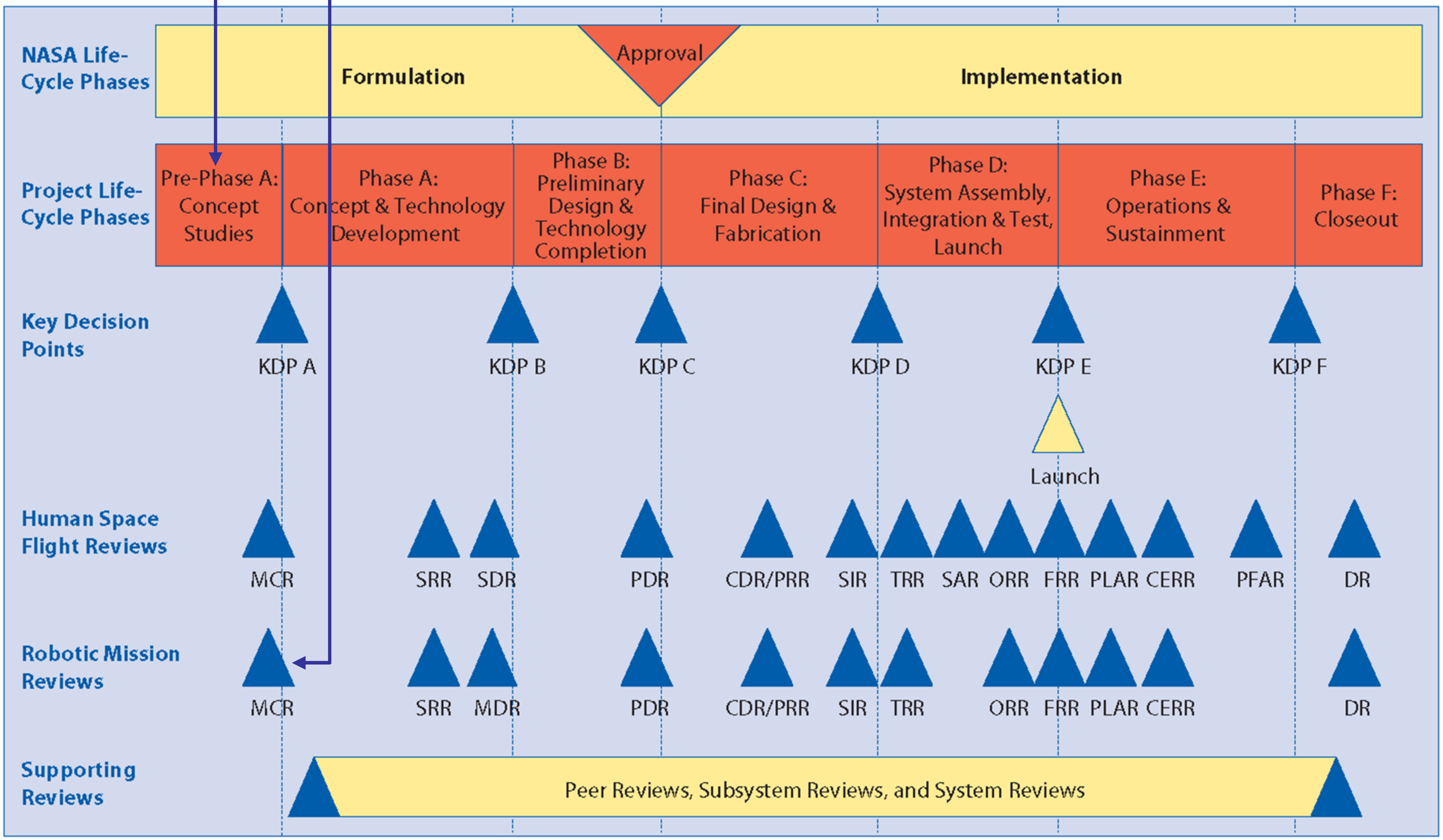
Notional Implementation Options



NASA Mission Life-Cycle*

GEO-CAPE is here

Need to be ready for a Mission Concept Review in FY'13



* Source: NASA/SP-6105 Systems Engineering Handbook, page 20

GEO-CAPE MCR Preparations

- Establish mission performance metrics (success criteria, aka measures of effectiveness – MOPs and associated Key Performance Parameters - KPPs)
- Conduct trade studies
  - Science requirements, to identify the significant cost vs. performance parameters
  - Mission risk (identify cost vs. reliability drivers)
  - Technology alternatives
  - Acquisition strategy
  - Mission operations approach
  - Data processing and distribution approach
  - Access to space (launch vehicle selection; co manifest; etc.)
- Develop / document the mission science requirements (STM and Level 1 req's)
- Explore a full range of mission implementation options to:
  - Define mission concepts that meet the Level 1 requirements
  - Investigate instrument and mission design and development alternatives, including make/buy decisions and different mission operations approaches
  - Identify the optimum range of cost, schedule, and capability that will maximize the science/cost ratio across the entire Decadal Survey flight program
  - Identify needed technologies and maturation plans
  - Identify potential partnerships with non-NASA organizations
- Draft a mission concept report that shows the mission is ready to start Phase A

GEO-CAPE Study Deliverables

- FY2011 Deliverables
  1. Instrument design studies and design lab exercises
  2. Leadership and support to the ESD activity to understand the issues and challenges with flying NASA payloads on non-traditional launches through the Hosted Payload (HPL) model
  3. Science outreach and international science partnership discussions
  4. Define the degree to which ocean and atmosphere observations must be simultaneous, and what degree of overlap is required
  5. Revised candidate mission science requirements delivered by the end of FY'11
  6. Support the ESM program office to complete a comprehensive assessment of the TRL level for all critical GEO-CAPE mission-enabling technologies, in particular including the full suite of potential GEO-CAPE instrument types

- FY2012 Deliverables
  7. Recommendation for either a dedicated or a distributed mission implementation

- FY2013 Deliverables
  8. Readiness to pass a Mission Concept Review (MCR) and begin mission formulation

Strawman GEO-CAPE Study Schedule

ID	Task / FY Quarter (Year)	Q1	2011 Q2	2011 Q3	2011 Q4	2011 Q1	2012 Q2	2012 Q3	2012 Q4	2012 Q1	2013 Q2	2013 Q3	2013 Q4	2013 Q1	Notes
1	**GEO-CAPE Community Workshop**			▲											
2	**Science Requirements**														
3	Science partnership discussions	■	■	■	■	■	■	■	△3						Partnership agreements with NOAA, EPA, international organizations / agencies
4	Baseline science requirements		■	△4											Scientific requirements that must be achieved to fully satisfy baseline science objectives
5	Simultaneous observations req.			■											Degree that ocean and atmosphere observations must be simultaneous / overlap
6	Observing scenario				■										Definition of observation pattern / pointing scenario over the science field of regard
7	Science descope options				■										Priority of science requirements; partial requirements fulfillment acceptability
8	Threshold science requirements				■										Minimum requirements which scientifically justifies performing the mission
9	STMs / L1 science req's published				△5										Draft Level 1 science requirements, measures of effectiveness (MOEs, KPPs)
10	**HPL Implementation Assessment**														
11	Government HPL		■	■											Assessment of GOES, TDRSS, DoD hosting opportunities
12	Commercial HPL			■	■										Updated data on commercial hosting opportunities and costs
13	HPL assessment report				△2										Hosting accommodations and opportunities (LRDs, payload mass, size, geometry, etc.)
14	**Instrument Design Studies**														
15	Instrument line-of-sight pointing study			■	■										Instrument line-of-sight pointing capability trade-offs, design concepts, costs
16	GeoMAC instrument study				■										GeoMAC instrument characteristics, capabilities, cost; cloud detection?
17	PanFTS instrument study					■									PanFTS instrument characteristics, capabilities, cost
18	CEDI instrument refinement study						■								CEDI design refinement (atmospheric correction, size minimization, etc.)
19	Planning payload instrument study report						△1								Summary descriptions of instrument concepts (characteristics, capabilities, costs)
20	**TRL Assessment**														
21	ESTO TRL assessment			■	■	■	■								Technical readiness and risks assessment of GEO-CAPE instrument concepts
22	TRL assessment report						△6								Technology readiness and maturation plan
23	**Mission Design Studies**														
24	Acquisition strategy			■	■	■									Preliminary acquisition strategies for all major procurements
25	Baseline mission study					■	■	■							Mission capability that fulfills baseline science objectives (dedicated, distributed)
26	Mission descope options							■	■						Reductions in mission capability / cost from baseline science down to threshold
27	Mission study report								△7						Mission architecture and system concept(s), cost and schedule, risks
28	**Mission Concept Review**														
29	Draft level 1 requirements document									■	■				Science objectives, instrument summaries, mission success criteria, etc.
30	Mission concept report									■	■	■			Mission architecture, system concept(s), acquisition approach, cost, schedule, risks
31	Preliminary integrated baseline										■	■			Project WBS, integrated milestone schedule, lifecycle cost, risk assessment, etc.
32	Preliminary formulation authorization document (FAD)											■			Mission purpose, authority, goals & objectives, participants, funding, reviews
33	Mission concept review (MCR)											△8			The MCR affirms the mission need and examines the proposed mission's objectives and the concept for meeting those objectives
34	**Key Decision Point A (KDP-A)**												★		NASA approval to begin formulation of the GEO-CAPE mission

Acquisition Strategy

- Use fair and open competition to get the best solutions from all potential suppliers (NASA, OGAs, Industry, Academia)

- Competitively select ALL instrumentation and host providers for all GEO-CAPE mission implementation options

- Make selections based on best value criteria
  - Delivers the greatest value
    - Provides the most science per NASA dollar spent
  - Is technically credible
    - The level of technical risk is understood, believable, and acceptable
  - Is manageable / feasible
    - Can be implemented as designed within fiscal and programmatic constraints
  - Is compatible with NASA strategic plans / programmatic constraints
    - Planned outcomes, timing, availability of resources

Progress Towards GEO-CAPE MCR

- Preliminary Assessment of Technology Needs Done
  - ☑ *No new technology needed to implement GEO-CAPE; technology developments could reduce costs and risks*
- Draft Level 1 Requirements Started
  - ☑ *STMs established with baseline and threshold science requirements*
- Acquisition Strategy Identified
  - ☑ *Instrumentation and host providers will be competitively selected*
- Potential Partnerships Identified
  - ☑ *Preliminary discussions with OGAs, International organizations, and U.S. commercial mission players*
- Multiple Mission Concepts Studied
  - ☑ *Implementation options studied for a traditional NASA only dedicated mission and for a phased set of hosted payload arrangements*
- Cost Estimates Developed
  - ☑ *Cost estimates developed using cost models and analogies to historic project and mission costs*
- Preliminary Schedules Drafted
  - ☑ *Phase duration estimates made based on past / recent experience from NASA Leo missions and commercial Geo missions*

Back up charts

GEO-CAPE Mission Study Background

- Fall 2009: GEO-CAPE Mission Design Group (MDG) was formed
  - Membership from HQ, GSFC, JPL, LaRC
- Jan 2010: first MDG instrument design study
  - Coastal Ecosystems Dynamics Imager instrument design lab (IDL) at GSFC
- Mar 2010: MDG study plan drafted / reviewed at SWG meeting in FL
  - DiJoseph_03-26-10_Study_Plan.pdf
- Aug 2010: first MDG mission design study
  - Hosted payload (HPL) implementation mission design lab (MDL) at GSFC
- Nov 2010: mission implementation concepts presented at Summative Review
  - Traditional NASA dedicated science mission
  - Commercial hosted payload phased implementation
- Jan 2011: received FY'11-12 Pre-Phase A study guidance from HQ/ESD

Mission Study Steps

Mission Study Team Formation and Study Plan Development

Study Definition

- Mission Goals and Objectives
- Mission Performance Evaluation Criteria
- Performance Evaluation Scoring Method

Concept Definition

- Top Level Mission Requirements
- Key Design Parameters and Prioritization
- Constraints and Assumptions

Concept Analysis

- End-to-End Mission Concepts
- Requirements Flow Down to System Concepts
- System Design Concepts

Concept Evaluation / Assessment

- Technology Readiness / Risks
- Performance per Evaluation Criteria
- Preliminary Cost & Schedule

Mission Architecture and System Concept Report / Review

NPR 7123 Requirements for MCR*

Mission Concept Review	
Entrance Criteria	**Success Criteria**
1. Mission goals and objectives.	1. The need for the mission has been clearly identified.
2. Analysis of alternative concepts to show at least one is feasible.	2. Mission objectives are clearly defined and stated and are unambiguous and internally consistent.
3. Concept of operations.	3. The preliminary set of requirements satisfactorily provides a system that will meet the mission objectives.
4. Preliminary mission descope options.	4. The concept evaluation criteria to be used in candidate systems evaluation have been identified and prioritized.
5. Preliminary risk assessment, including technologies and associated risk management/mitigation strategies and options.	5. The mission is feasible. A solution has been identified that is technically feasible. A rough cost estimate is within an acceptable cost range.
6. Conceptual test and evaluation strategy.	6. The cost and schedule estimates are credible.
7. Preliminary technical plans to achieve next phase.	7. An updated technical search was done to identify existing assets or products that could satisfy the mission or parts of the mission.
8. Defined Measures of Effectiveness (MOEs) and Measures of Performance(MOPs).	8. Technical planning is sufficient to proceed to the next phase.
9. Conceptual life-cycle support strategies (logistics, manufacturing, and operation).	9. Risk and mitigation strategies have been identified and are acceptable based on technical risk assessments.

* NPR 7120.005D page 19 points to NPR 7123.1A – Appendix G3

GEO-CAPE Mission Study Guidance

- Guidance for FY-11 and FY-12 GEO-CAPE mission concept (Volz)
  - The GEO-CAPE team has made good progress on instrument design studies showing reductions in the size of the candidate instruments are feasible. The team should continue those activities into FY2011, including additional design lab exercises.
  - Through summative reviews, ESD identified the need for a program level assessment activity to understand the issues and challenges with flying NASA payloads on non-traditional launches through the Hosted Payload (HPL) model. The GEO-CAPE team should provide leadership and support to the ESD program activity completing these pathfinding activities in FY2011.
  - Science outreach and international science partnership discussions should continue as proposed. The mission science team should further define the observing and science requirements, in particular to define to what degree the parallel observations must be simultaneous, or what degree of overlap is required. A revised set of candidate mission science requirements should be delivered at the end of FY2011.
  - With the results of the HPL pathfinder activity, and an additional iteration on the mission science requirements the mission team should be ready to make a recommendation by the end of FY2012 for either a dedicated or a distributed mission implementation.
  - The team should work with the Technology Readiness Level (TRL) assessment activities led by the ESM program office during the FY2011 period, to complete a comprehensive assessment of the TRL level for all critical GEO-CAPE mission-enabling technologies, in particular including the full suite of potential GEO-CAPE instrument types.