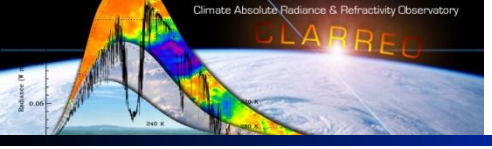
CLARREO Summary for New SDT Members

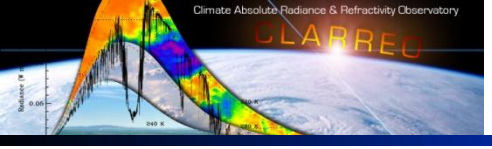
Climate Absolute Radiance & Refractivity Observatory

January 31, 2011



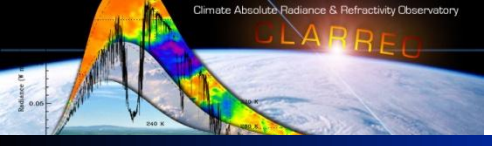
Extended Pre-Phase A White Paper

- The CLARREO project was directed on Feb 28, 2011 to develop a plan for extended Pre-Phase A for FY12 – FY16
  - This plan is described in the White Paper distributed to the team in late March
  - Includes continued support for the Science Team and studies of alternative methods of achieving the CLARREO science goals
  - The plan has been briefed to NASA HQ and we are awaiting a decision on the funding level for FY12 and beyond
  - HQ remains very supportive of the CLARREO science goals and our approach to mission definition, including science value/cost trades
  - Many missions before CLARREO have gone through long extended pre-phase A stages before finally reaching launch.
- This presentation will give a brief summary of the white paper and allow time for questions and clarifications if needed.



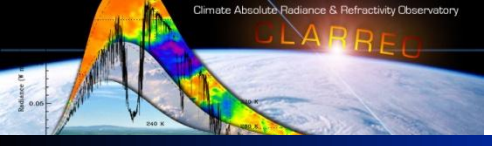
Extended Pre-Phase A White Paper

- HQ guidance on the white paper:
- Consider the Science Definition Team (SDT), LaRC and GSFC project and science staff, and other procurement costs for FY12 through FY15.
- The plan should assume that the SDT is fully funded in FY11, but that funding levels in FY12 and beyond might be lower (e.g. 0 to 30%)
- The competitively selected SDT is considered a "covenant" by HQ.



Extended Pre-Phase A White Paper

- White paper began with a brief overview of the CLARREO science goals from the level 1 requirements document
- The paper then defined a *baseline* and *threshold* budget for continued pre-phase A research to support CLARREO.
- Baseline:
  - refocus CLARREO science and engineering on less expensive options that can capture smaller but significant portions of the CLARREO science goals.
  - science study scope will have to expand beyond those considered leading up to the MCR mission design
  - but science and engineering studies can proceed at a much slower pace since we are not on a path to a specific launch date.
  - baseline is relevant to NASA's R&A program: broader impact than just CLARREO
  - publication of prior and future science studies as well as publication of a report sufficient for use in the next Earth Science Decadal Survey
  - complete Calibration Demonstration Systems (CDS) for IR and RS spectrometers to demonstrate SI traceability at CLARREO accuracy and retire instrument risk.
  - baseline budgets are bottoms up analysis of tasks to be performed.



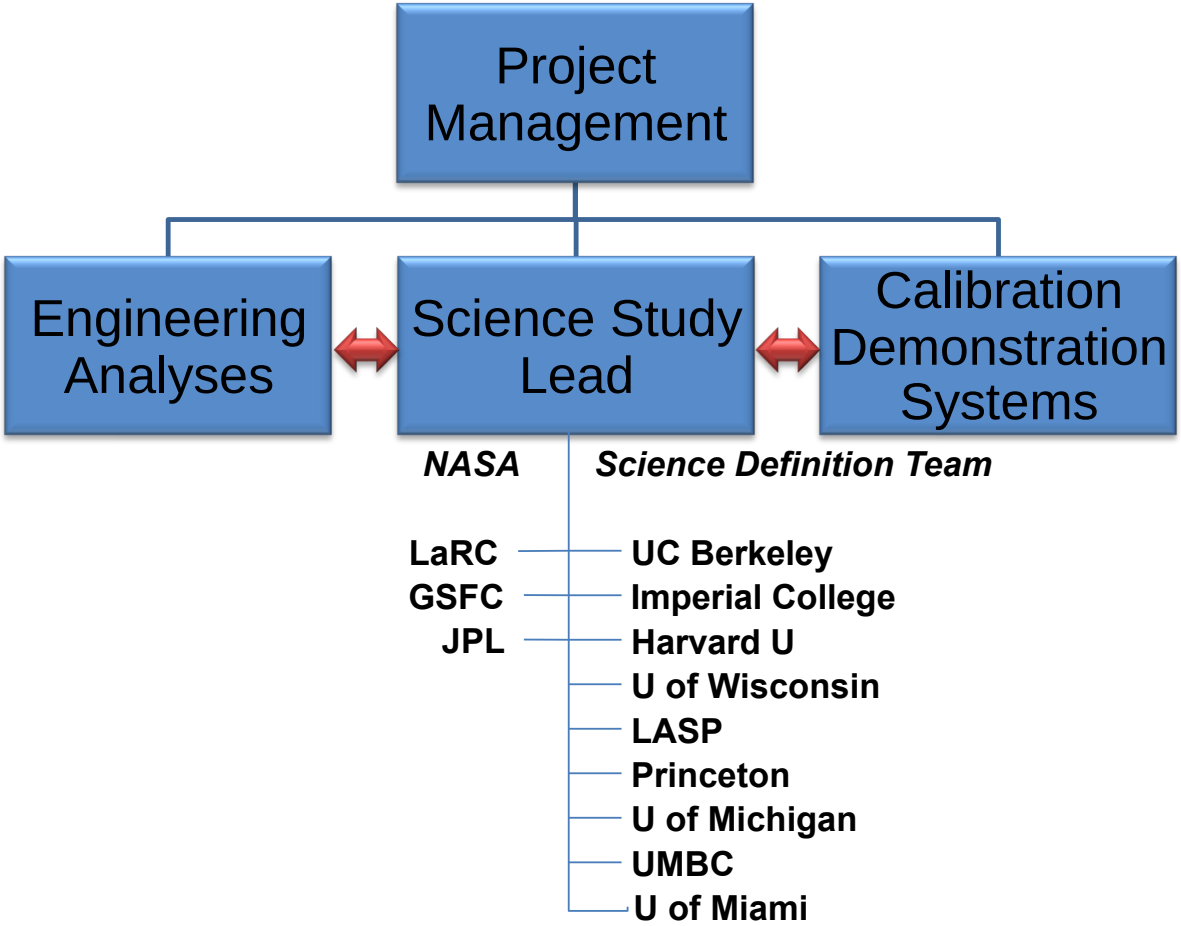
Extended Pre-Phase A White Paper

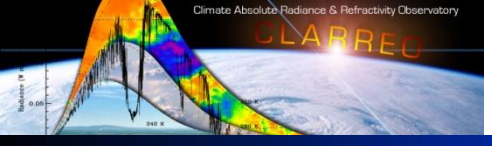
- Threshold:
  - seriously reduced science, engineering, and risk reduction activities
  - very high risk approach to ultimate recovery of the CLARREO mission capability
  - impacts of the threshold approach given in the final section of the white paper

- Need for an integrated Science, Mission Design, and Calibration Demonstration System to meet HQ guidance on CLARREO.
  - previous CLARREO pre-phase A effort was successful because of its highly integrated team: one of the major "strengths" pointed out by the MCR review board in Dec 2010.
  - we propose a smaller effort that still maintains the integration of science studies, engineering trades, SI traceability risk reduction, and ability to respond to a wider array of options for the mission with contributed mission components (e.g. space station, international collaboration, DoD or JPSS rideshare, etc.)
  - use experienced CLARREO staff part time to maintain continuity and avoid the lost time and resources of starting from scratch with new personnel later
  - continue the use of the science value matrix approach to explore a wider range of mission options for cost/risk/science value.

Extended Pre-Phase A White Paper

- Proposed management structure:

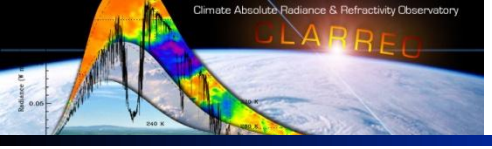




Extended Pre-Phase A White Paper

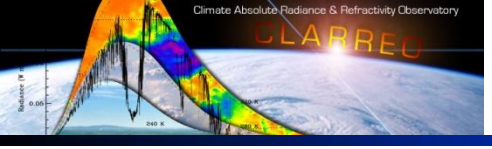
- Science Study Goals
  - *Advance the CLARREO IR/RS/RO climate change science*
  - *Determine the impact of alternate mission concepts on CLARREO science and thereby enable science value/cost trades through use of the CLARREO Science Value Matrix approach*

- Advance the CLARREO IR/RS/RO climate change science
  - In essence an R&A type science investigation joining the external SDT with the LaRC and GSFC science investigations
  - Over 80% of the SDT can be considered classic R&A science with broad climate science impact. Only 17% was directed at more mission specific research
  - Broader studies include extension and improvement of the climate OSSEs, spectral fingerprinting of decadal climate change, reference intercalibration at climate change accuracy, improved RO at both lower and higher altitudes than typical 5-20km, and studies of the stability of satellite retrieval algorithms when applied to decadal change
  - Extend all previous studies to more realistic conditions (e.g. OSSEs, sampling, fingerprinting, reference intercalibration)



Extended Pre-Phase A White Paper

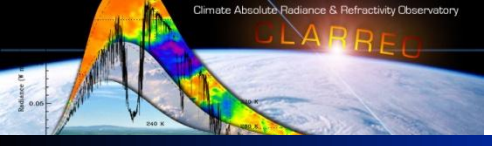
PI	Organization	Research Objectives
Ao	Jet Propulsion Laboratory	SI-Traceability analysis for GNSS RO Ionospheric residual errors and stratospheric retrieval Lower troposphere bias and depth penetration GNSS RO climate data analysis
Brindley	Imperial College London	Assessment of natural variability in the resolved infrared spectrum and the emergence of climate change signals Analysis of satellite sampling and instrument characteristics in trend detection
Collins	UC Berkeley	Continued OSSE execution; Detection and Attribution Analysis Comparison of variability in SCIAMACHY data / OSSE variability Testing time-to-detection results based on OSSE spectra. Simulating infrared and solar spectra Expansion of the OSSE infrastructure to different climate models
Dykema	Harvard University	SI traceable uncertainty analysis of IR measurements Formulation of IR calibration and validation plans
Huang	University of Michigan	Simulations of IR spectra using high-resolution climate models Using CLARREO data to test and validate global climate models
Leroy	Harvard University	Evaluate climate signal pattern uncertainty using perturbed physics ensembles Investigate transient climate change and detection times Next generation radiance simulation / performance evaluation for joint IR, RO, RS trend detection Climate use of GNSS RO Finalize the error budget for the upper troposphere Investigate possible RO benchmarking of the lower troposphere, 0–5 km Investigate possible RO benchmarking of the stratosphere, 20–50 km Contribute a spatially-dependent cumulative error budget
Pilewskie	University of Colorado	Trend Detection in RS Spectral Radiances
Revercomb	University of Wisconsin-Madison	IR SI-traceable uncertainty analyses and post-launch validation approaches Defining approaches for using CLARREO data for testing and improving climate projections Retrieval stability for climate trend analyses IR Intercalibration assessment studies
Soden	Univ. of Miami	Radiative Kernels as a Tool for Diagnosing Climate Feedbacks
Strow	University of Maryland Baltimore County	Evaluate accuracy of in-orbit spectral calibration, or validation, of CLARREO Accuracy and stability of the CLARREO spectral calibration Explore ways to determine climate trends from hyperspectral data retrievals
Xiong	NASA GSFC	RS Intercalibration assessment studies SI-Traceable uncertainty analyses for RS



Extended Pre-Phase A White Paper

- Science Study Goals, part 2:

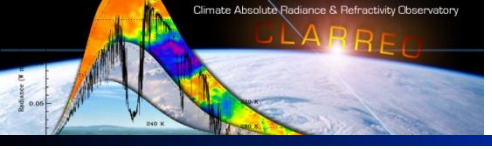
- Broaden the Science Trade Space: alternative mission options
  - Expand the mission trade space to ways that portions of the CLARREO mission could be achieved
  - Examine alternative orbits such as space station, Iridium, NOAA, EUMETSAT, DoD ESPA ring
  - Examine lighter, lower power, less capable, but less expensive instruments
    - example: impacts of decreased spectral resolution/coverage, decreased accuracy, increased noise
  - Extend the science value matrix approach to help consider this broader range of options. This tool has been endorsed by NASA HQ, the MCR review board, as well as the recent co-chairs of the Decadal Survey (Berrien Moore, Rick Anthes)



Extended Pre-Phase A White Paper

- Science Deliverables
  - Complete journal publication of pre-phase A research to date.
  - Continue to document extended pre-phase A research in journals, conferences, and reports.
  - Produce a broader report of mission/science options analogous to the space science "blue books" that is more comprehensive than individual narrowly focused journal papers.

- Science Tasks
  - Examination of the approach outlined above leads naturally to a list of science tasks to be carried out during the Extended Pre-phase A research.
  - Tasks are based on experience from the last 3 years of CLARREO research
  - Tasks are also based on the SDT proposed science activities
  - With lower funding: must phase tasks over time in FY12 thru FY15
  - Assumes SDT will again be recompeted after 3 years
  - Takes into consideration other engineering/mission options

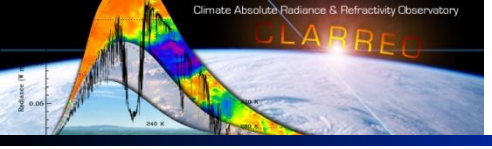


Extended Pre-Phase A White Paper

CLARREO Refocus Activities and Deliverables

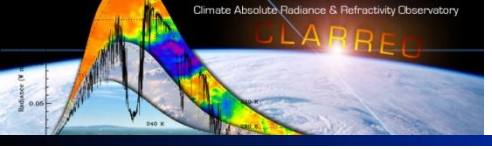
Deliverables are shown in bold text

Science Study Focus Area	Organizations	2011	2012	2013	2014	2015
IR SI Traceability	LaRC/NIST/UW/Harvard/UK/Italy	SI Design	CDS Analysis	Dev Inst Model	**Test Inst Model**	**Final Report**
RS SI Traceability	GSFC/NIST/LASP/UK-NPL	SI Design	CDS Analysis	Dev Inst Model	**Test Inst Model**	**Final Report**
IR Spectral Inst. Reductions: Capability/Cost	LaRC/GSFC/UW/Harvard	Limit Spectral	Vary Accuracy	Alt Methods	**Alt Methods**	**Final Report**
RS Spectral Inst. Reductions: Capability/Cost	GSFC/LASP	Limit Spectral	Vary Accuracy	Alt Methods	**Alt Methods**	**Final Report**
Decadal Change Climate OSSEs	UC Berkeley/U Michigan/Canada	IR/RS/RO	Alt Orbits	Clim. Sensitivity	AR5/CFMIP	**Final Report**
Climate Change Spectral Fingerprinting	LaRC/Berkeley/LASP/Miami	Fast RS code	IR/RS/RO	Nonlinearities	Cloud Amt/Prop	**Final Report**
Climate Change Reference Intercalibration	LaRC/GSFC/UW/NOAA/GSICS	Alt Orbits	Polariz Models	Alt Methods	**Alt Methods**	**Final Report**
Suborbital Options for IR Reference Intercal	UW/LaRC/NIST	Aircraft	Aircraft	Airships	Airships	**Final Report**
Suborbital Options for RS Reference Intercal	LASP/LaRC/NIST	Aircraft	Aircraft	Airships	Airships	**Final Report**
Decadal Stability of Retrieval Algorithms	LaRC/UMd	IR tests	IR/RS tests	IR/RS Methods	**IR/RS Methods**	**Final Report**
Orbital Sampling for Spectral Fingerprinting	LaRC	Alt Orbits	Natural Var	Alt Methods	**Alt Methods**	**Final Report**
Orbital Sampling for Reference Intercalibration	LaRC	Alt Orbits	Natural Var	Alt Methods	**Alt Methods**	**Final Report**
GNSS-RO Improvements for climate change	Harvard/JPL/LaRC	< 5 km	< 5 km	> 20km	> 20 km	**Final Report**
Data Systems to Support Studies	Pleiades Supercomputer/ASDC	OSSEs/Analysis	OSSEs/Analysis	OSSEs/Analysis	OSSEs/Analysis	
Documentation: Journal Papers, Reports		**All**	**All**	**All**	**All**	**All**
CDS Focus Area						
IR Calibration Demonstration System (CDS)	LaRC/GSFC/NIST	Assemble	**Complete/Cal**	Cal/Cap Trades	Cal/Cap Trades	**Final Report**
RS Calibration Demonstration System (CDS)	GSFC/NIST	Assemble	**Complete/Cal**	Cal/Cap Trades	Cal/Cap Trades	**Final Report**
Engineering Focus Area						
Reduced IR Instrument Studies	LaRC/GSFC	Preliminary Design / Cost	Accommodation Assessment	Science Value Assessment	Science Analysis / Design Update	**Final Report**
Reduced RS Insrument Studies	GSFC/LaRC	Preliminary Design / Cost	Accommodation Assessment	Science Value Assessment	Science Analysis / Design Update	**Final Report**
Accomodation and Access to Space Analyses	LaRC	Identify Options	Cost Analysis / Verification	Science Analysis / Design Update	Finalize options and costs	**Final Report**



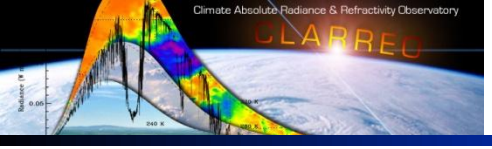
Extended Pre-Phase A White Paper

- Engineering Trade Studies
  - Mission Analysis and Design
  - Engineering portion of Science Value Matrix update
  - Instrument Conceptual Design study results
    - reduced spectral resolution/coverage/accuracy, increased noise
    - capability with instruments reduced from 60-70 kg range to 20-30 kg?
    - vary instrument lifetime design
  - Instrument Accommodation Analysis Studies
    - International Space Station
    - ESPA ring
    - Iridium
    - JPSS
    - International missions
  - Calibration Demonstration Test Report(s)
  - Access to Space Opportunities
  - Combine reports into "blue book" summary



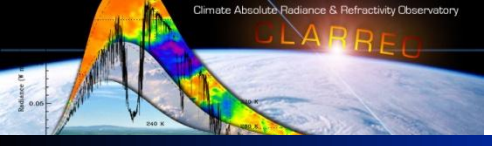
Extended Pre-Phase A White Paper

- Calibration Demonstration System Studies
  - Major CLARREO objective is improvement in spaceborne instrument traceability to SI standards at climate change accuracy: i.e. gaps could occur with minimal degradation of the climate record accuracy and confidence over decades.
  - Demonstrate in the lab that instruments similar to the CLARREO MCR designs could achieve the SI traceability requirements:
    0.1K (k=3) for IR, and 0.3% (k=2) for RS.
  - Demonstrate that this capability can be moved from the NIST labs to NASA and/or instrument vendors for future instruments
  - Collaborate with NIST on this activity
  - The IR CDS has been in construction at LaRC, and the RS CDS at GSFC. LASP has an IIP funded for this type of demonstration, and Harvard/UW have also had an IIP activity funded of this type.
  - Successful completion of these activities could greatly reduce the risk of developing and successfully launching such high accuracy instruments into orbit.
  - Provide a test bed for end to end SI traceability error analysis, and studies of alternative detectors, sources
  - Deliverables include peer reviewed documentation of SI traceability chain.



Extended Pre-Phase A White Paper

- Calibration Demonstration System Tasks
  - Complete CDS assembly/integration/test in early FY12
  - CDS test plan / calibration process and procedures / instrument uncertainty model / SI traceability path
  - CDS operation/determine uncertainties/verification of SI traceability
  - Peer review including NIST of SI traceability achieved including uncertainty analysis of traceability chain
  - Performance models will be used to support science studies of changes in instrument design



Extended Pre-Phase A White Paper

- Impacts of Threshold vs Baseline Extended Pre-phase A
  - Impacts are severe and chance of recovering parts of the CLARREO mission through alternative mission designs is significantly reduced
  - Elimination of completion and use of the Calibration Demonstration Systems: seriously diminishing risk reduction, future cost savings, and ability to evaluate alternative instrument designs at lower size/cost
  - 25% reduction in climate OSSEs. reduced OSSE accuracy, realism, confidence, and increased risk in alternative mission designs.
  - Eliminate suborbital study options (e.g. aircraft, airships)
  - Eliminate studies of the stability of reflected solar retrieval algorithms for decadal change: CLARREO is the only group planning such studies (including ROSES)
  - Reduce RS reference intercalibration studies by 50%. Greatly increases risk of evaluating alternative mission designs and instrument designs.

Extended Pre-Phase A White Paper

- When do we get an answer from NASA HQ on the White Paper?
  - No specific date, but we hope to hear within the next month
  - This, like many things, is wrapped up in administration and congressional struggles with future budgets

Backup Slides