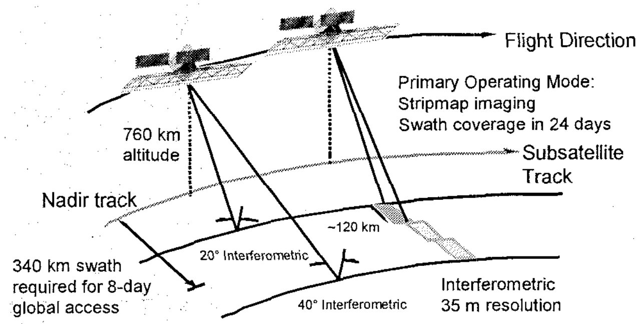
InSAR

Interferometric Synthetic Aperture Radar

Mission Objective: *The InSAR mission objective is to provide the first dedicated spaceborne interferometry mission to precisely map Earth surface deformation due to tectonic, volcanic, and glacial processes. The resulting data will uniquely allow characterization and quantification of underlying processes enabling predictive models.*

Science Objectives:

- *Characterize and understand strain changes in tectonically active areas leading to and following major earthquakes*
- *Characterize three dimensional magma movements leading to better prediction of volcanic eruptions*
- *Assess the impact of ice sheet and glacier system dynamics on sea level rise and characterize temporal variability*



Mission Requirements:

- *5-year lifetime*
- *10-minutes of data per orbit (average)*

Navigation and Orbit:

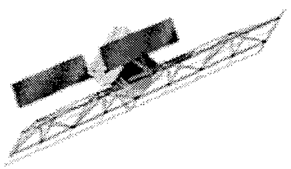
- *Sun synchronous 6am/6pm*
- *760 km, 98.5°*
- *250 m diameter orbital tube*

Operations:

- *Simple 8-day repetitive mission cycle*
- *Two S/X-band Ground Stations*
- *Selected ground automation*
- *Distributed processing architecture*

Project Implementation:

- *JPL instrument electronics build*
- *Commercial spacecraft bus; antenna panels, structure, and deployment mechanism*
- *Precision GPS as GFE to spacecraft bus contractor*
- *JPL I&T of phased-array antenna and radar electronics*

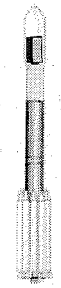


Flight System:

- *Commercial spacecraft bus*
- *GPS for Precision Orbit Determination/Nav.*
- *Selected-to-full redundancy*

Launch System:

- *Delta II 2920-10*



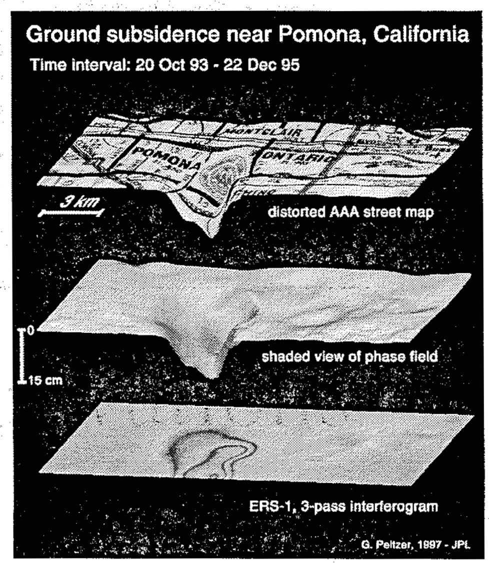
Payload System:

- *Repeat pass radar interferometry*
- *3-D vector deformation by observing*
  - *while pointing to the left and right*
  - *on ascending and descending orbits*
- *L-band single-polarization (HH) radar*
- *Full redundancy of radar electronics*
- *Stripmap, High-Resolution and ScanSAR Modes*
  - *Primary operating mode – Stripmap Mode (continuous strip-mapping with 3 possible beams)*

InSAR Mission Motivations

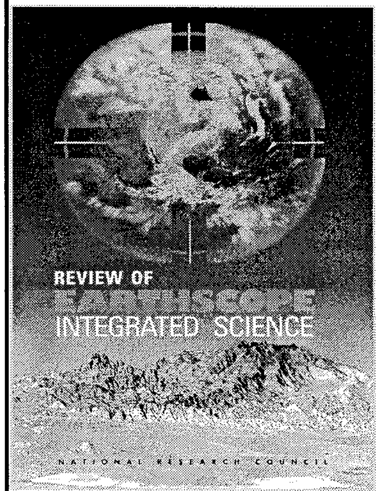
- We live on a restless planet subject to earthquakes, volcanic eruptions, destructive floods, landslides, subsidence, and other hazards.
- The Earth's surface is always changing and understanding these changes is key to development of a predictive capability that could minimize loss of life and property damage.
- InSAR surface deformation measurements to the centimeter level will increase our understanding of the solid Earth system and improve predictive models.

Earthquake damage is related to size and location. The Northridge earthquake was a $20 billion event.

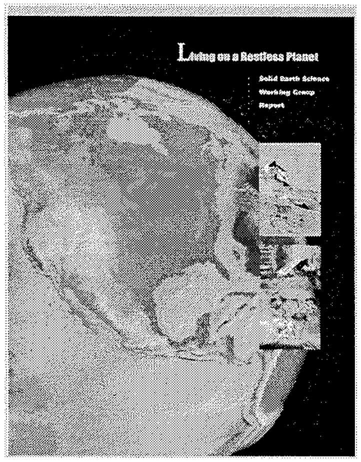


InSAR can also detect land subsidence, sinking of the land due withdrawal of water and oil.

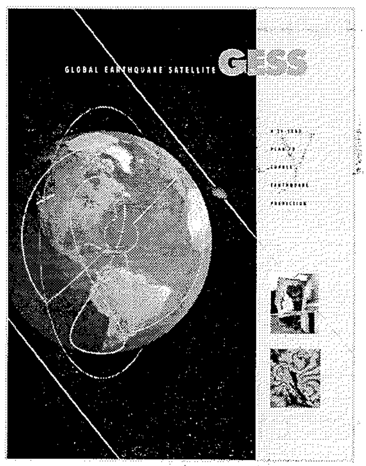
Science Community Involvement



The Earthscope Initiative from NSF calls for an InSAR mission as a critical component of the Earth laboratory.



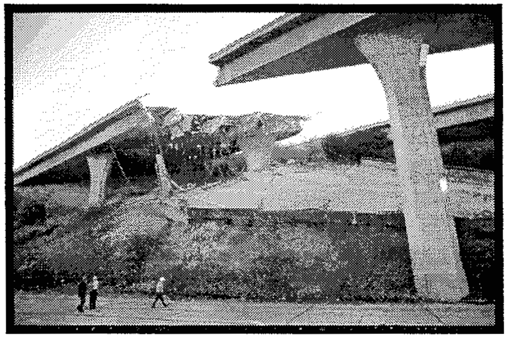
The Solid Earth Science Working Group, an independent panel of scientists, recommends InSAR as the highest priority.

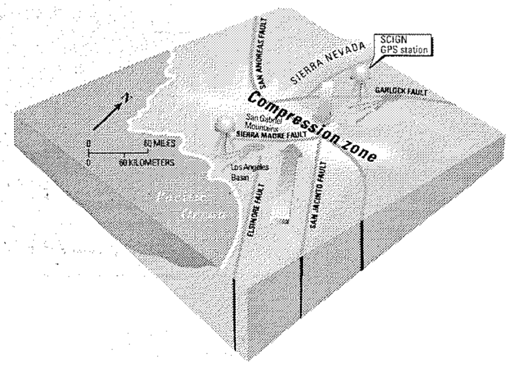


The Global Earthquake Satellite System lays out a plan to enable Earthquake forecasting over the next two decades.

Science Community Involvement – Cont'd

The need for a dedicated InSAR satellite to monitor and measure crustal deformation has been intensively studied and repeatedly endorsed by the scientific community.





Living on a Restless Planet: Solid Earth Science Working Group Report, 2002, p. 59.

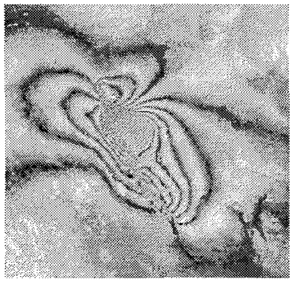
"In the next 5 years, the new space mission of highest priority for solid Earth science is a satellite dedicated to interferometric synthetic aperture radar (InSAR) measurements of the land surface at L-band. Such a mission would address the most urgent objectives in the areas of plate-boundary deformation, land-surface evolution, ice and sea-level change, volcanism, and mantle dynamics.

Global Earthquake Satellite Study Report, 2003, p.14.

A space based system for monitoring crustal deformation is the logical next step to achieve revolutionary advances in earthquake science needed to develop a better predictive capability.

Science Justification and Implementation

•**Justification:** InSAR Responds to Solid Earth Questions Posed by NASA, NSF



–INSAR identified as the highest priority measurement by the Solid Earth Science Working Group Report (SESWG-p.59).

–The Global Earthquake Satellite Study Report recommends: "A space based system for monitoring crustal deformation is the logical next step to achieve revolutionary advances in earthquake science needed to develop a better predictive capability (Global Earthquake Satellite Study Report, 2003, p.14). They go on to urge development of 'InSAR Everywhere All the Time' within 25 years.

–The major NSF funded EarthScope project now underway to understand crustal processes in the western US consists of 4 measurements, 3 are funded by NSF. InSAR is the fourth and key spaceborne measurement required, yet unsatisfied.

–Earthquakes and volcanic eruptions have caused the greatest natural disasters in history, yet the processes by which these events occur are poorly understood. Predictions will not occur without understanding.

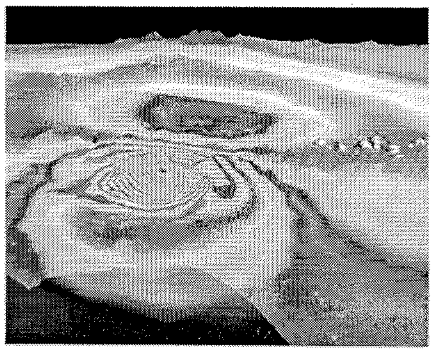
–Cryospheric changes and sea level rise have the greatest potential impact on civilization on the medium term. Global inventory of ice budgets lack required precision and temporal/spatial coverage. Recent discoveries highlight our ignorance. Trillions of dollars of coastal infrastructure and communities are at risk.

•Implementation: Frequent, high precision, geographically comprehensive, surface deformation measurements are practical only via a dedicated InSAR satellite with specifications outlined here.

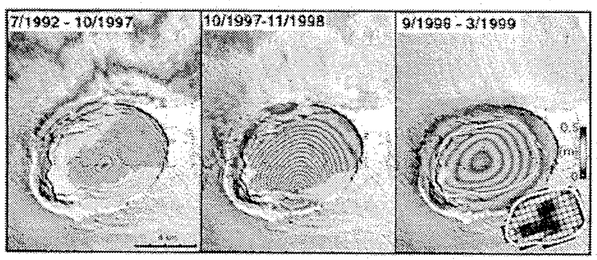
Science Objectives and Goal

- **Principal Science Objective:**
  - Precisely map Earth surface deformation due to tectonic, volcanic, and cryospheric processes over a five year mission life.
  - The resulting data will uniquely enable characterization and quantification of underlying processes enabling predictive models.
- **This objective can only be achieved via a dedicated spaceborne radar interferometry mission.**
- **Baseline Science Targets:** Tectonic areas, Volcanoes, and Cryosphere.
- **Goal:** InSAR derived deformation maps of baseline target areas at required temporal frequency and resolution.

Tectonic Areas



Volcanoes



Cryosphere

Options for Further Consideration: Application Science Targets

- ***Coastal Process/Subsidence*** What are the rates and spatial characteristics of coastal subsidence, how does this relate to coastal environmental change, coastal infrastructure, public safety, and homeland security? Coastal processes, particularly subsidence, conspire with sea level rise to place trillions of dollars of infrastructure and communities at risk. Regional, high precision subsidence and decorrelation measurements will aid risk assessment, mitigation, and severe storm response and recovery.
- ***Primary target area***-US Gulf Coast of Louisiana, adjacent Texas and Mississippi-good proof of concept area.
- ***Problem statement:*** The Gulf Coast near the Mississippi River is subsiding due to the load of the river sediments. Inundation due to combined subsidence, fluid withdrawal, sediment compaction, and sea level rise is occurring. Some areas are subsiding at up to **3 cm/yr**. Plackerman's Parish is below sea level. Port Fourchon and other critical infrastructure is at risk. GPS and conventional surveys provide a precise but spatially and temporally incomplete understanding of the problem. The Louisiana Spatial Reference Center (LSRC) is the research and data center for coordinated work with other agencies including NOAA and the NGS, and is interested in InSAR application to this problem.
- ***Requirements for Coastal Process/Subsidence***
  - InSAR data collected at every opportunity over target area (90% acquisition success).
  - InSAR coverage from approximately Houston Texas to Pascagoula Mississippi, ~700 km east-west and ~400 km north from the Gulf Coast.
  - Standard InSAR data availability, data to be processed by LSRC (Louisiana Spatial Reference Center).

Options for Further Consideration: Experimental Science Targets

- ***Mountain Glacier Mapping.*** These glaciers are rapidly moving and melting, poorly constrained contribution to sea level rise, and are difficult to study due to inaccessibility.
  - *Requires InSAR satellite to be inserted temporarily into 2 day repeat orbit.*
- ***Can InSAR Decorrelation Maps Provide Useful Data for Areas of Destruction*** related to earthquakes, fires, severe storms, floods, landslides, or other major disasters?
  - *Requires targets of opportunity with baseline and post event InSAR data during the mission.*
- ***What is the Relationship Between Regional Crustal Deformation and Gravity?*** GRACE data may provide a unique opportunity for simultaneous analysis and modeling. InSAR mosaic capability under development.
  - *Requires regional InSAR mosaics, Antarctica suitable target, augment ongoing GRACE studies.*
- ***Soil Moisture:*** InSAR measurements to complement Hydros mission. Interferograms of soils have been shown to be a partial function of moisture content, which can be tested/developed against Hydros data.
  - *Requires observations of Hydros calibration targets at appropriate times.*

Options for Further Consideration: Experimental Science Targets – Cont'd

- ***Vegetation Biomass Mapping via Non-zero Baseline Orbit:***
  - *Requires InSAR satellite initially inserted into an orbit 1 km displaced from the baseline "deformation" orbit, the resulting interferograms of vegetated areas would provide data for deriving tree heights and for profiling forest vertical structure.*
  - *24 days in this orbit in ScanSAR Mode would provide a global vegetation data set. A bonus would be additional topographic data for use in generation of baseline mission interferograms.*
- ***ScanSAR Global Land Surface InSAR Data 4 Times per Year.***
  - InSAR and GPS data to date have yielded repeated surprises about the mobility of the earth's crust. Other unanticipated phenomena may be observed if the data are collected and studied by curiosity driven scientists.
  - *Requires adequate on board storage and data system implications.*

Current Project Implementation/Assumptions

- Project Implementation
  - JPL instrument electronics build
  - Commercial spacecraft bus; antenna panels, structure, and deployment mechanism(s)
  - Precision GPS (Global Positioning System) hardware will be GFE (Government Furnished Equipment) and provided to the spacecraft bus contractor
  - JPL I&T (Integration and Test) of phased-array antenna and radar electronics
- Assumptions
  - InSAR project starts in FY 05
  - Currently there are no international collaborations

InSAR Mission Summary

InSAR Baseline Architecture

- Science Objectives
  - Characterize and understand strain changes in tectonically active areas leading to and following major earthquakes
  - Characterize three dimensional magma movements leading to better prediction of volcanic eruptions
  - Assess the impact of ice sheet and glacier system dynamics on sea level rise and characterize temporal variability
- Flight System
  - Commercial spacecraft bus
  - 256 Gbits min on-board storage
  - 300 Mbps X-band science downlink
  - Left/right pointing
  - 5-year mission lifetime, with selected-to-full redundancy
  - GPS for Precision Orbit Determination/Nav

InSAR Mission Summary – Cont'd

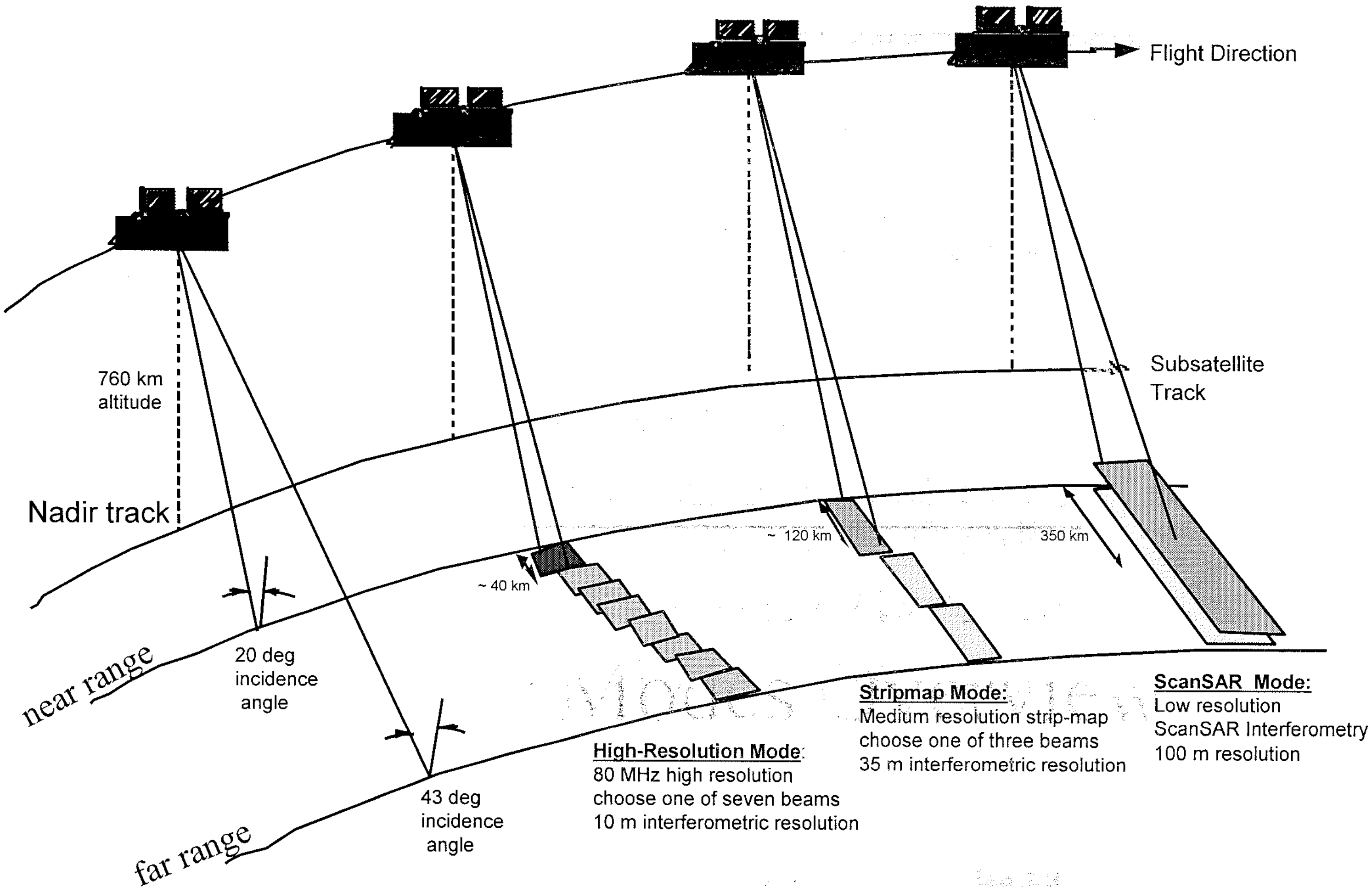
InSAR Baseline Architecture

- Payload System
  - Procured phased-array antenna panels, structure, and deployment mechanism(s)
  - L-band single polarization (HH)
  - Full redundancy of radar electronics
  - Stripmap, High-Resolution and ScanSAR Modes
    - Primary operating mode – Stripmap Mode (continuous strip-mapping with 3 possible beams)
- Navigation and Orbit
  - 250 m diameter orbital tube
  - Sun-sync 6am/6pm, 760 km, $i = 98.5^0$
  - 8-day exact repeat
- Operations
  - 10 min average data per orbit; 24-hr latency
  - High-latitude X- band receiving stations – ASF & Svalbard
  - Distributed processing software
  - Selected ground automation
- Launch System
  - Delta II 2920-10

InSAR Radar Modes Overview

- Shown on the following slide is the observing geometry for the satellite platform and the relative swath sizes for the three modes (Stripmap Mode, High-Resolution Mode and ScanSAR Mode).
- The near range incidence angle is 20 degrees (18 degree look angle).
- The far range incidence angle is 43 degrees (37 degree look angle).

InSAR Radar Modes Overview



Meeting Observational Requirements at 10 Minutes of Data per Orbit

- Baseline Design is 10 Minutes Average of Data per Orbit
- The Following Maps Show Coverage of Science Targets at 10 Minute Average
  - Satisfies basic science requirements. Key concern is ability to beat down tropospheric effects, more frequent observations improve this.
  - At 23 minutes per orbit ALL targets can be imaged from 4 directions every 48 days w/ 100 km swath width, or every 16 days w/ ScanSAR.
  - Significant improvement in data quality achieved w/higher temporal repeat.

Highest Priority Target: Plate Boundary Observatory Region US

•InSAR for Western US PBO area shown in white - 4 directions every 48 days