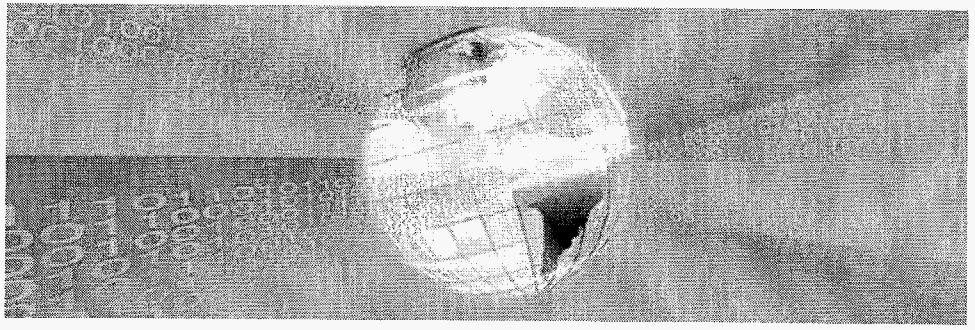
NonVo latileMem ory TechnologyS ymposium20 02



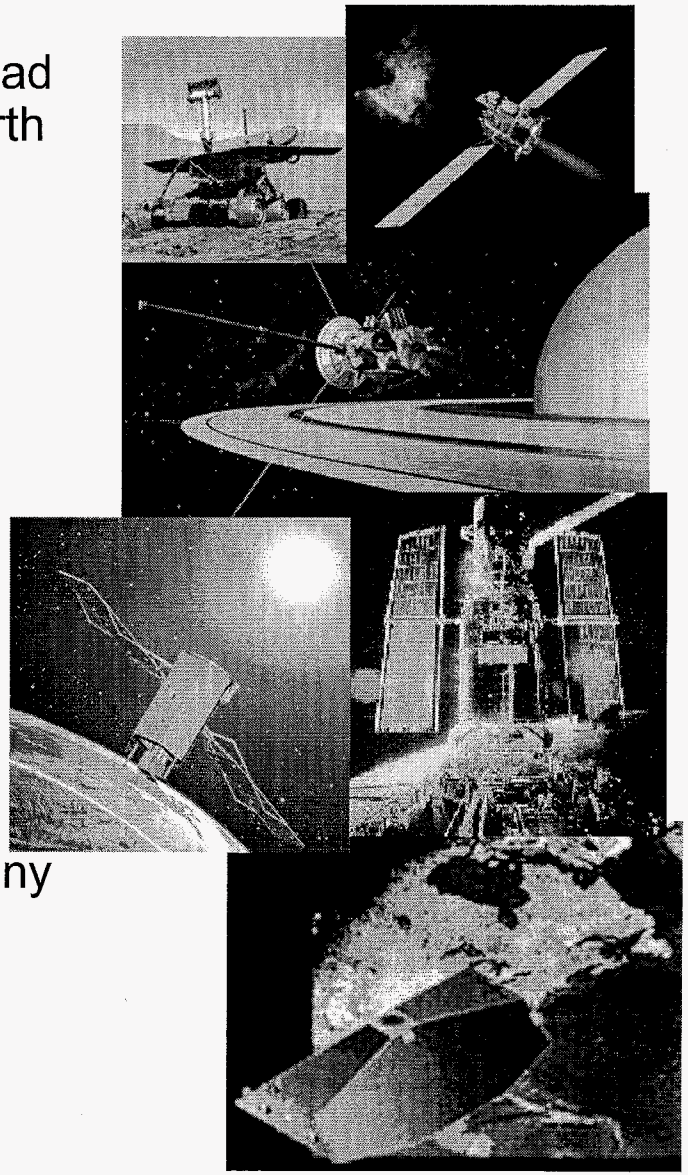
The Missions of the Jet Propulsion Laboratory

Dr. DavidC risp
Jet PropulsionLa boratory
California InstituteofTechn ology

November5,20 02

JPL Missions

- TheJe t PropulsionL aboratory (JPL)co nductsa b road rangeo fsp acecraftmission st o supportN ASA's Earth andSp ace Science Programs
  - Advancedrob oticspacecraft
  - Instrumentsfor detailed scientific investigations
- NASA Earth ScienceEn terprise(ESE)
  - SolidEar th
  - Oceans
  - Atmosphere
- NASA Officeo f SpaceScien ce(OSS)
  - SolarS ystemEx ploration
  - Sun-EarthC onnection
  - Astronomical Searchfo rOr igins
- Highd ensity, lowp ower, radiation hardn on-volatile memory systemsa rea n enabling technology forma ny oft hesea pplications.
- Thisp resentation will
  - Provideanovervi ewofJ PL'songoi ngE arthandSpace Sciencemis sionsand futurespacefli ghtoppo rtunities
  - highlightspeci ficar easw hereadvancednon-volati le memorycapab ilities aren eeded.



Earth Science Enterprise

The EarthS cience Enterprise (ESE)co nducts space-based investigationsth at addresses fivesci entifict hemes:

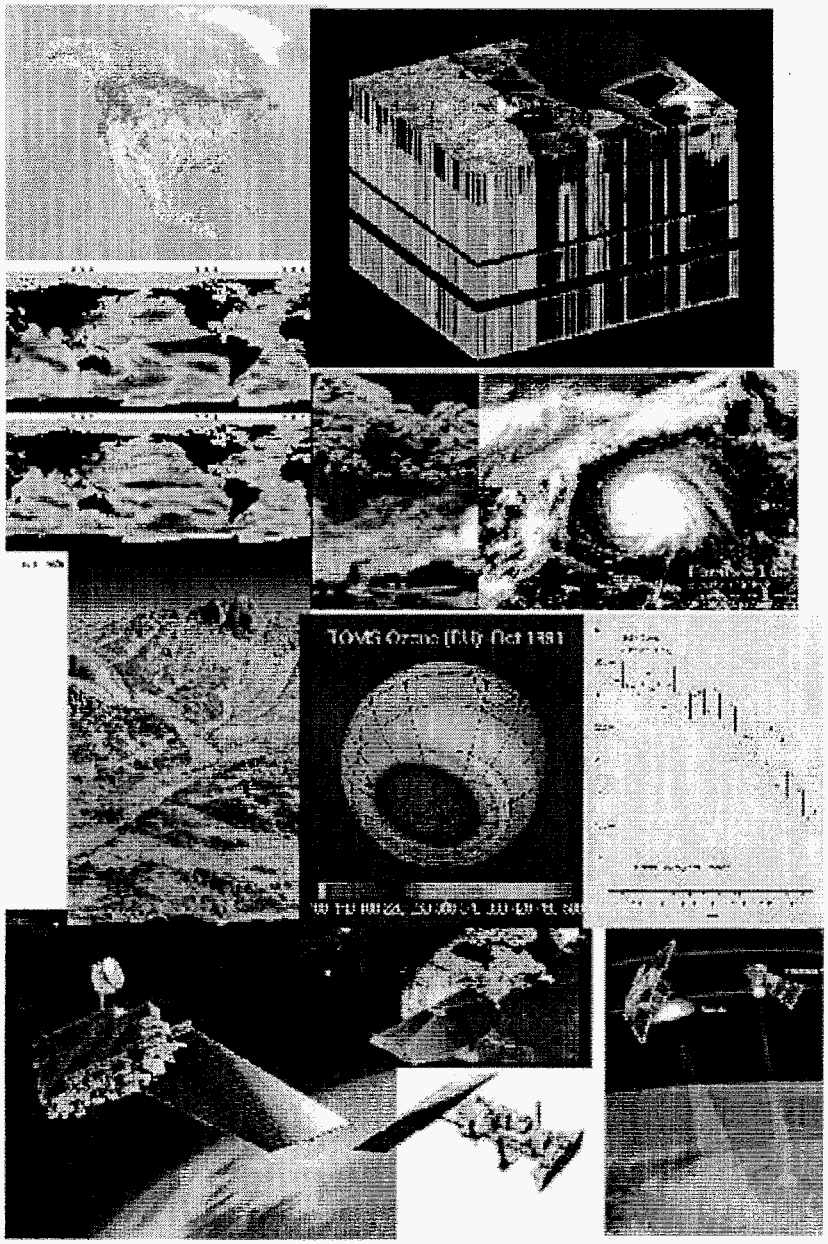
(i) Biologyand Biogeochemistryof Ecosystemsan dthe Global CarbonCy cle

(ii) Atmospheric Chemistry, Aerosols, andS olar Radiation

(iii) GlobalWater and Energy Cycle,

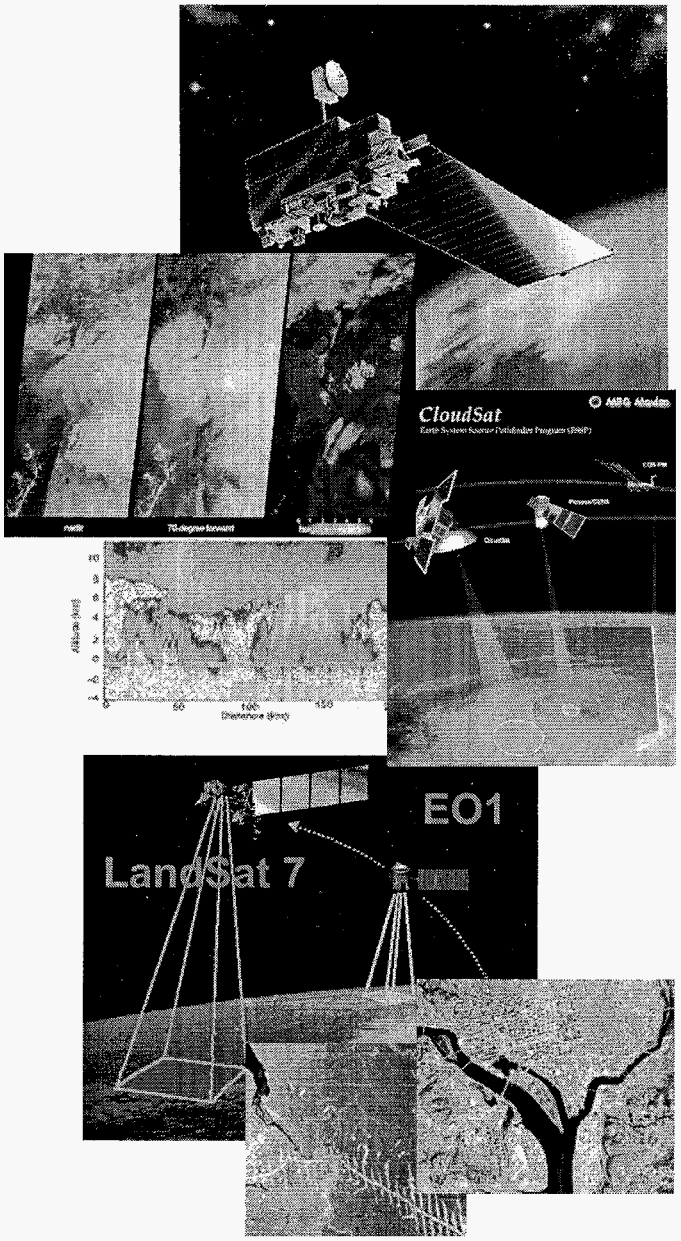
(iv) Oceansan dIce, and

(v) SolidEart hS cience.



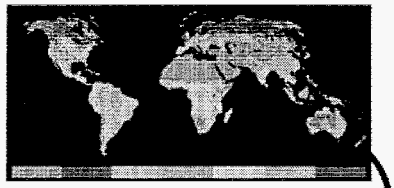
Earth Science Missions

- LargeSyst ematicMea surementMissions thata ddressEarthsy stems cience
  - Earth Observing System
    - Terra,Aqua, AuraPlatfo rms
    - FuturePl atforms
  - LandSat
  - JPL supportsth ese missionsa sa n instrumentp rovider(MI SR,AIR S,ML S, TES)
- EarthPr obesPr ogram
  - Topex/Poseidon, ACRIMSat,Q uikSat
  - PI-LedESSPMission s
    - JPLManagestheGRACE, CloudSat, Aquarius,andO CO
- NMPESE
  - Earth OrbitingMission s: EO1, EO3
  - JPL Managest heN MPPro gram forN ASA



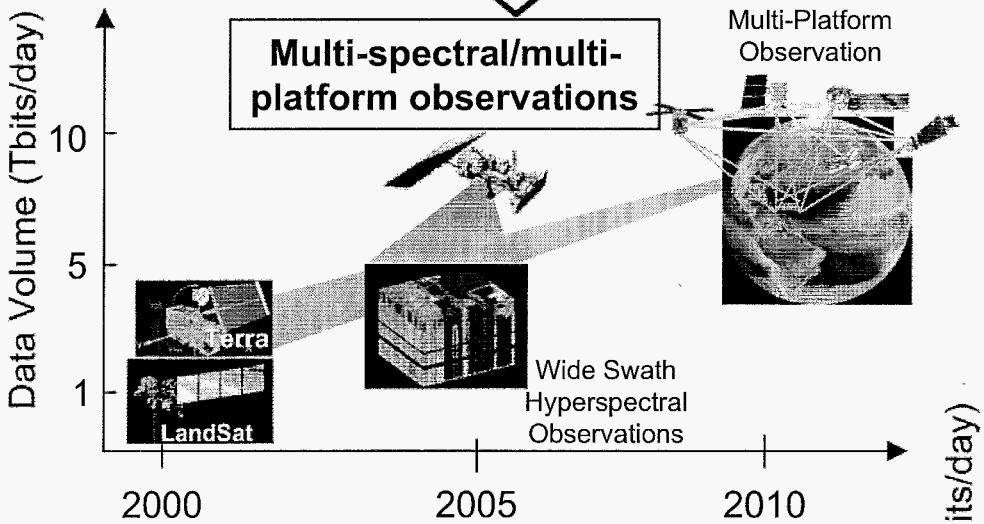
Science Drivers for Communication and Data Processing Technologies

Changesin G lobal LandC over/Use



CarbonCyc le PrimaryProd uctivity

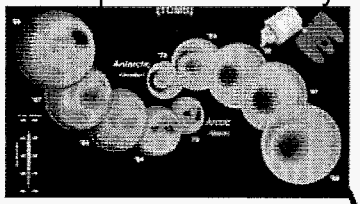
Improvements in Spatial/Spectral/Temporal Resolution and Coverage



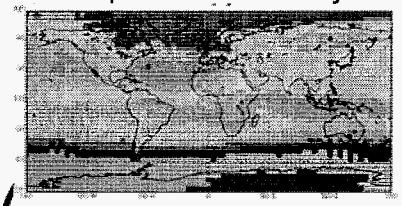
Data Volumes:

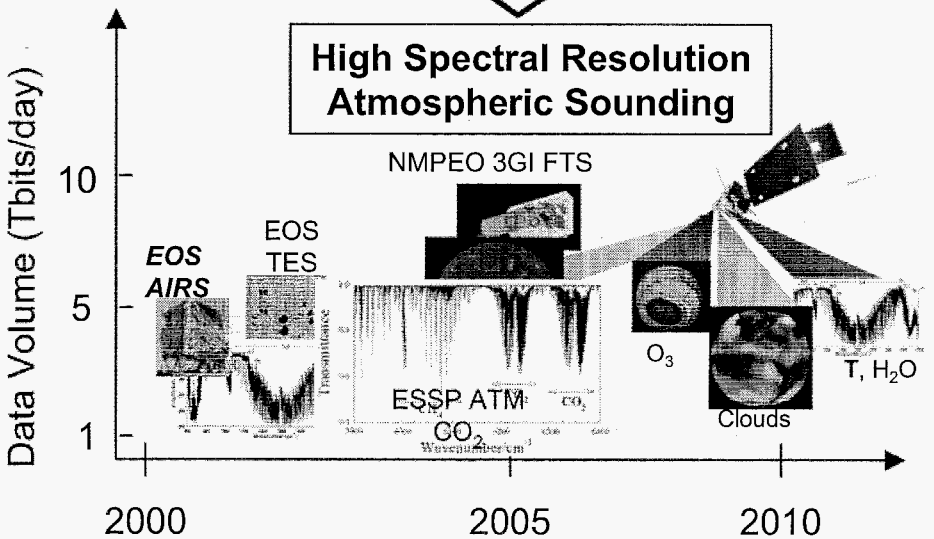
- Hyperspectral Imaging
  - 30m reso lution,2 00 kmwid eswa th, 1024cha nnels,1 6-bits/pixel
  - >24M b/s (>2Tb its/day)
- Atmospheric Spectroscopy
  - 1kmreso lution,60 0km wide swa th 4098cha nnels,1 6-bits/pixel
  - >16M b/s(>1.4 Tbits/ day)

StratosphericCh emistry

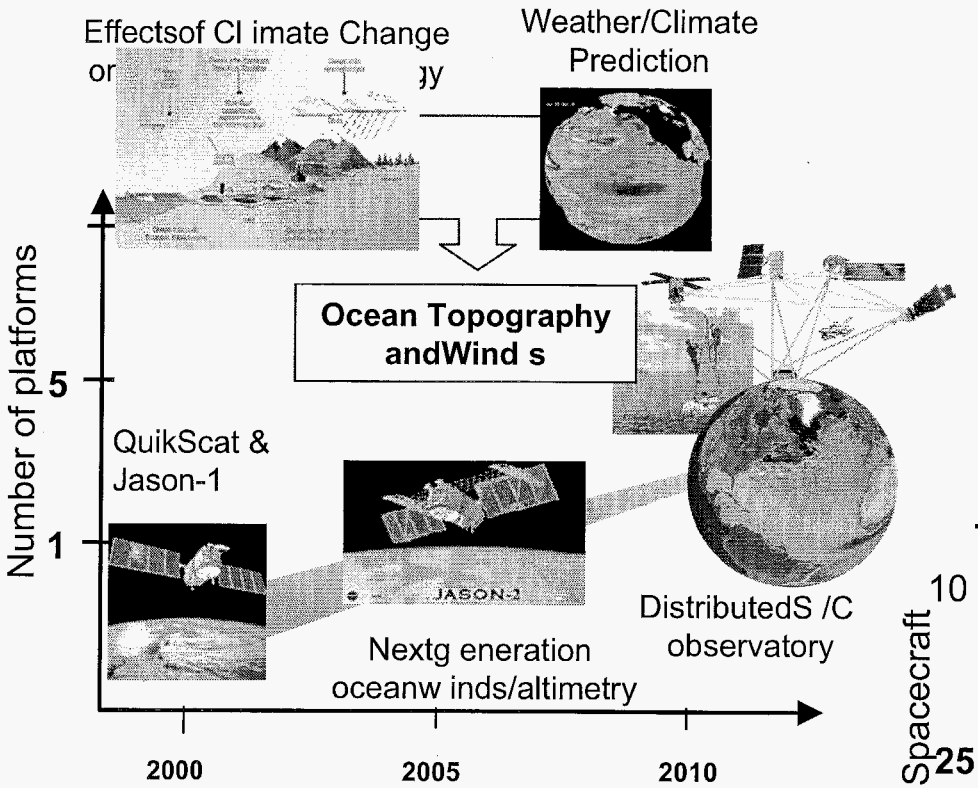


AtmosphericCarb onCycle





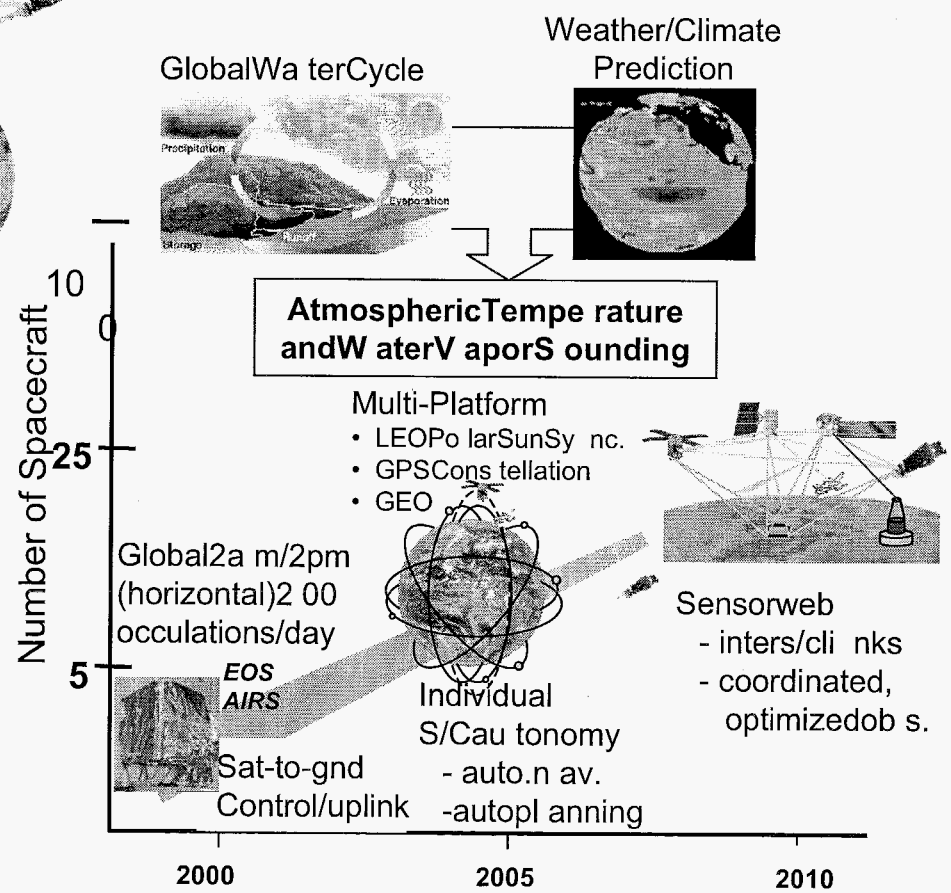
Science Drivers for Distributed Platform Technologies



Otherd istributedmea surements:

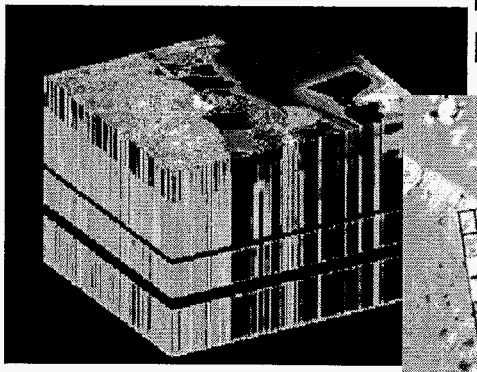
- VolcanoMoni toring
- SurfaceD eformation
- EarthR adiationBudget

Coordinated and Distributed Observatories

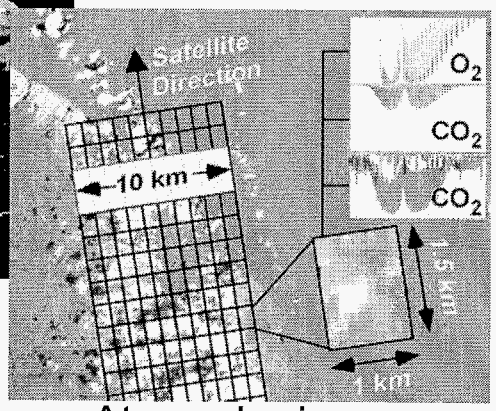


ESE Drivers for Memory Technologies

- Large data volumes
  - Hyperspectral Imaging
    - 10'so f Gbit/orbit
    - 10-20o rbits/day
    - Limitedd ownlinko pportunities
  - Interferometry
    - Veryla rged atase ts collected, processed, andre sampled on-board priort o downlink
  - On-board Processingfor advancedau tonomy
    - Targetingse quences
    - Constellation ephemerides
- Radiationh ardsyste ms
  - LEO:S AAPass age
  - MEO/GEO
    - Highra diatione nvironment
    - Long-lived systems

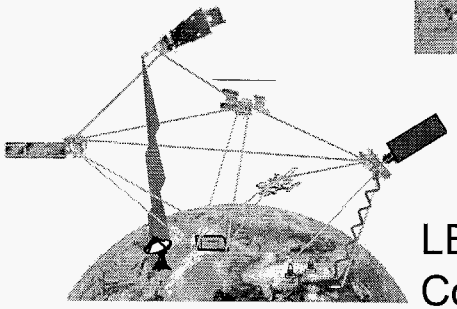


Hyperspectral ImageC ube

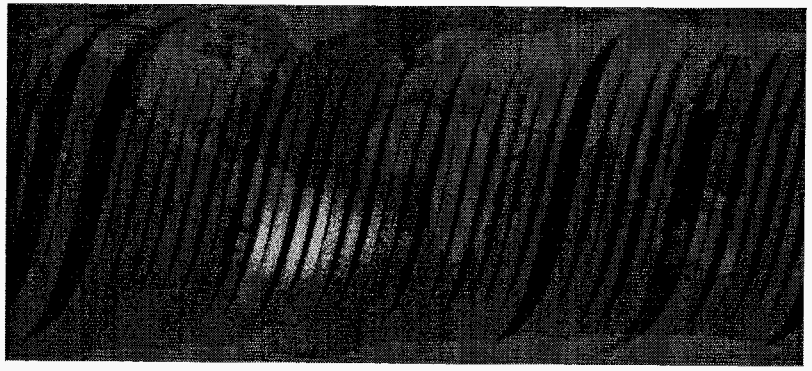


Atmospheric Chemistry(OCO)

GOES



LEO/GEO Constellation



EOSMI SRdar kfra messhowi ngcosmic rayhitsarou ndSouth Atlantic Anomaly

Space Science Missions

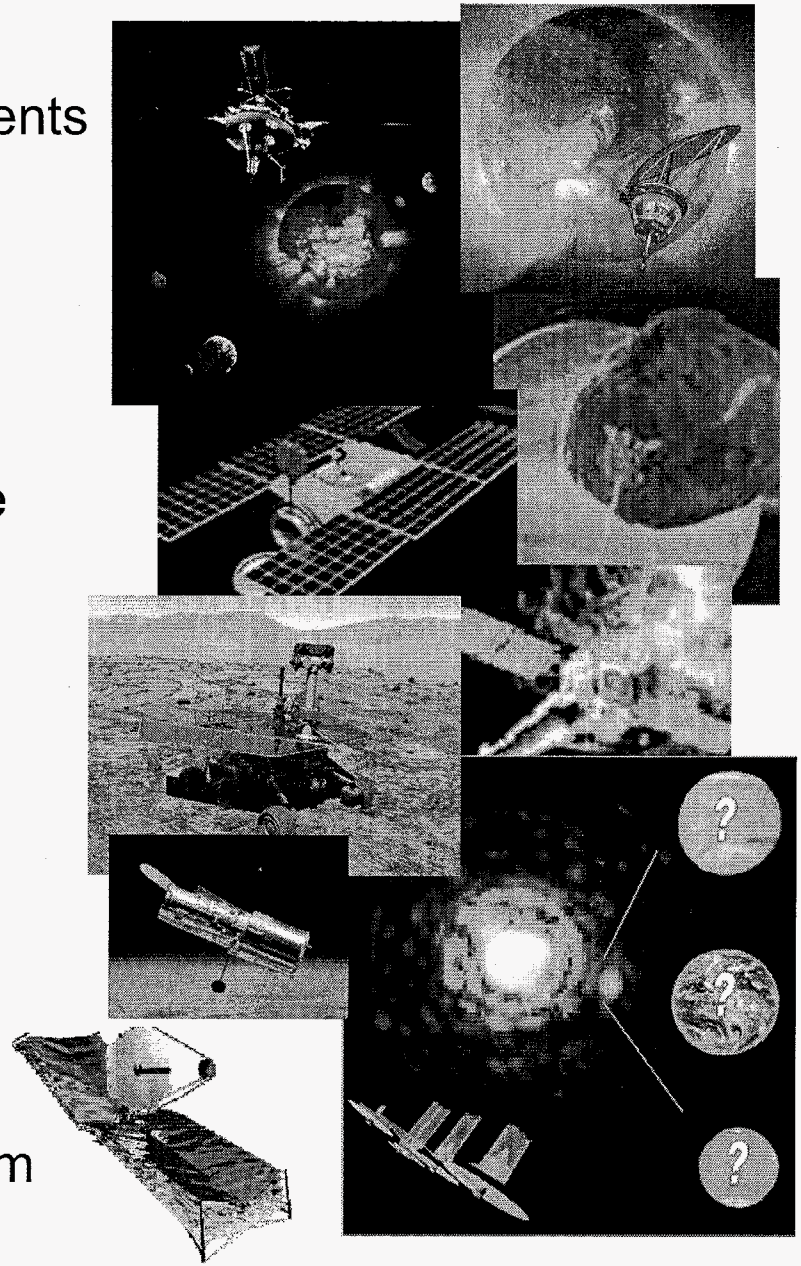
TheO ffice ofSpa ceSc iencecon ducts basic researchan dspa ce flightexpe riments toanswer thef ollowingqu estions:

- How didt heu niverse begina nd evolve?
- How didw eg eth ere?
- Wherea rew eg oing?
- Are wea lone?

Thesequ estionsaread dressedwithinthe scopeoffou rma jorthe mes

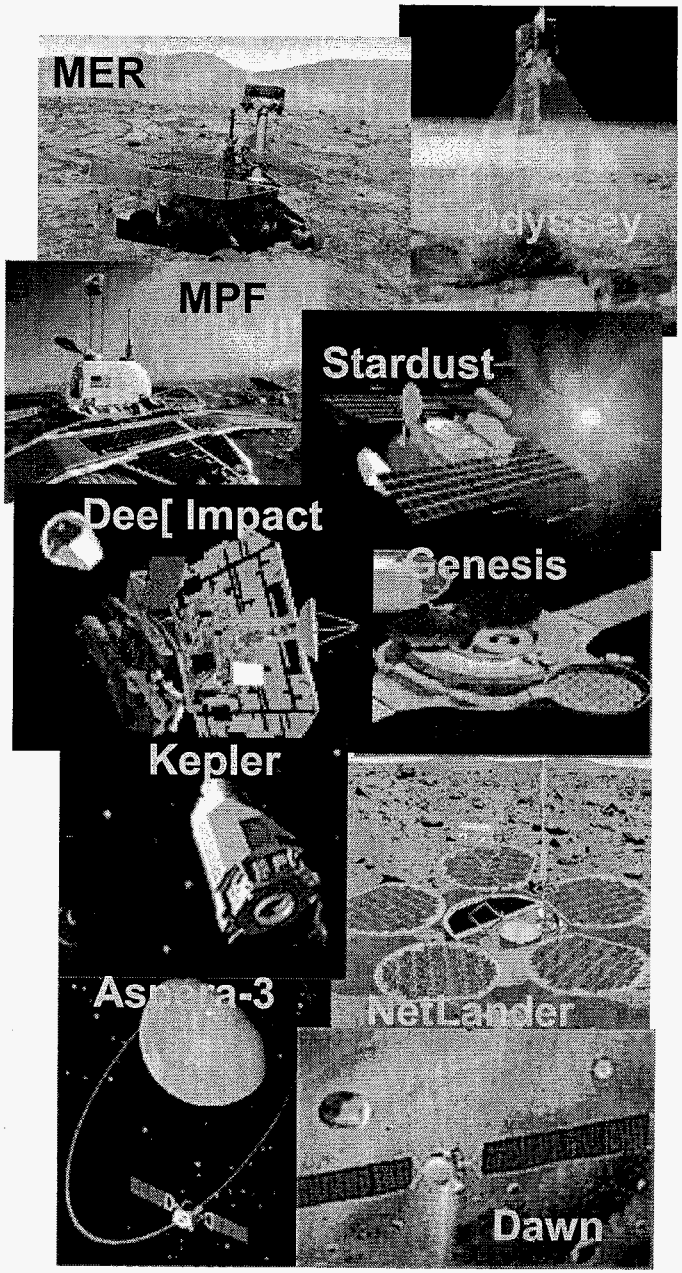
- SolarSyste m Exploration
  - SolarSy stemExpl orationD ivision
  - MarsExpl orationProgra m
- Sun-Earth Connection
  - Sun-EarthConnecti onDiv ision
- Structure and Evolution of theU niverse
  - Astronomya ndPhys icsDi vision
- Origins
  - Astronomya ndPhys icsDi vision

JPLpla ysmajo rr olesint heSola rSy stem Explorationan d OriginsThe mes



Solar System Exploration

- MarsExp lorationPro gram
  - IntermediateC lass Missions
    - MER,MRO , Smart Lander
  - PI-LedMar sScouts
    - Proposalss ubmitted inre sponset o the firstA O currentlyun der evaluation
- DiscoveryPro gram
  - FocusedPI-ledMis sions
    - AO's releasedvery1.5to2 years
    - $325M budgetcap,no radioisotopes
    - Focusedprima rilymission st otheon the inner solars ystem
  - JPLman agedthe majorityof these missions
    - MarsP athfinder,S tardust,G enesis
    - Underd evelopment:Dee pI mpact,K epler Dawn
  - MissionsofOpp ortunity:NASApay loadsonnon-NASAm issions
    - MarsE xpress ASPERA-3
    - MarsNetLan der SEIS, ATMIS,N EIGE
- New Frontiers Program
  - FirstAO tober eleasedearlyi n2 003
  - $650M – enables outplanet missions



Next Generation SSE Missions

JPL

NASS olarS ystemD ecadalS urvey

Cross-cuttingt hemes

Firstbillion yearso f solarsy stemhist ory

Volatiles and organics – the stuff oflif e

Origin and evolutionofhab itable worlds

Processes:h owplan ets work

Mars Missions

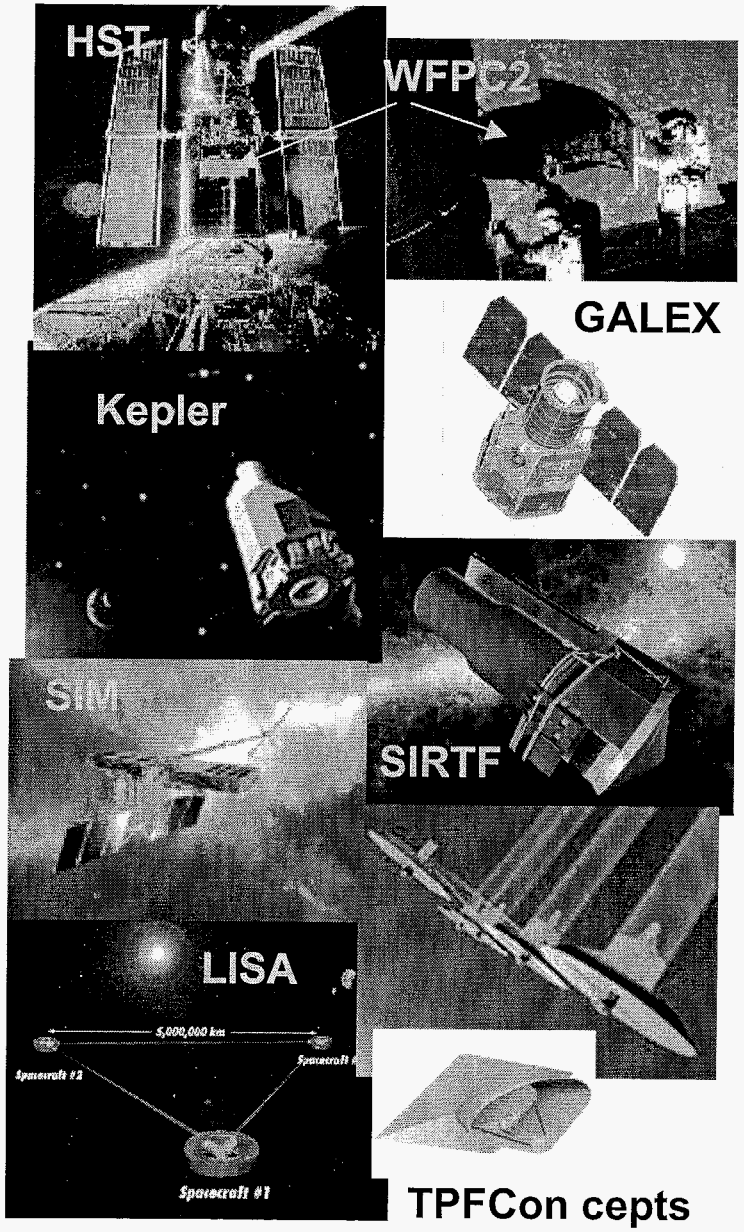
- SmallMis sions
  - PI-ledMa rsSco utmission s at eacho pportunity
- IntermediateCla ss
  - SmartLa nder
  - Long-lived Network
- Large Missions
  - Mars Sample Return

Other Planetary Missions

- SmallMiss ions(Discovery)
  - PI-ledmission sa t 18mo nthint ervals
- Intermediate Class(NewFrontiers)
  - Kuiper Belt/PlutoExp lorer
  - SouthPo le/Aitken BasinSa mple Return
  - Jupiter PolarO rbiterw ithPro bes
  - Venus in-situe xplorer
  - CometSu rface Sample Return
- LargeMis sions
  - Europa GeophysicalEx plorer

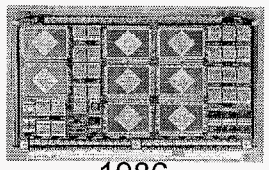
Origins Missions

- Great Observatories
  - Ongoing
    - HubbleSpaceTele scope Wide FieldP lanetary Camera-2(HST WFPC2)
      - Inservic esin ceDe cember19 93
    - SpaceInfraRed TelescopeF acility (SIRTF)
      - Preparingfo rl aunch
  - UnderDevel opment
    - Spacel nterferometerMissio n(S IM)
  - Proposed
    - TerrestrialP lanetFind er(TPF)
    - LaserInter ferometerS paceA ntenna (LISA)
- Explorers Program
  - SmallEx plorers(SMEX)
    - Plledmiss ionwit ha$75 Mcostcap
    - The JPL-managedG alaxy Explorer(G ALEX) mission ispre paringforlau nch
  - MediumClas sExplorer s (MIDEX)
    - JPLis contributing tot wo missions thatar e currentlyin competition
  - Missions ofOppo rtunity:
    - NASAp ayloadso nno n-NASAm issions
- DiscoveryPro gram
  - Kepler– thefirst Discoverymissi on for Origins



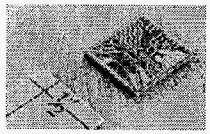
Deep Space Mission Technology Drivers for Memory Technologies

- Radiationha rd systems
  - Intenser adiatione nvironments:
    - Europa GeophysicalEx plorer
  - Long-livedsyst ems
    - Kuiper Belt/Pluto Explorer
    - MarsL ong-Lived Network
    - Great Observatories
- Larged atavolu mes
  - Hyperspectral Imaging
    - MarsReconnai ssance Orbiter
  - Interferometry
    - Europa GeophysicalEx plorer
    - TPF,L ISA
- On-board Processing
    - Advancedautonomy
      - Ion-PropulsionS pacecraft(e.g.Dawn)
      - CometS urfaceS ampleRetur n
      - Mars Smart Lander
    - Datahandli ng
      - Mars NetLander, SmartLa nder,Lo ng-Lived Network



1986
GlobalBulkM emory
12.7x22.9x1.5cm
9.2M bits,~ 70W

1993
GlobalBulk Me moryM CM
5.08x10.2x0.64cm
9.2M bits,~20 W



1999
256M bit MemoryCu be
0.76x0.76x0.43cm~1 W

Technology Requirementsfor Non-VolatileM emory

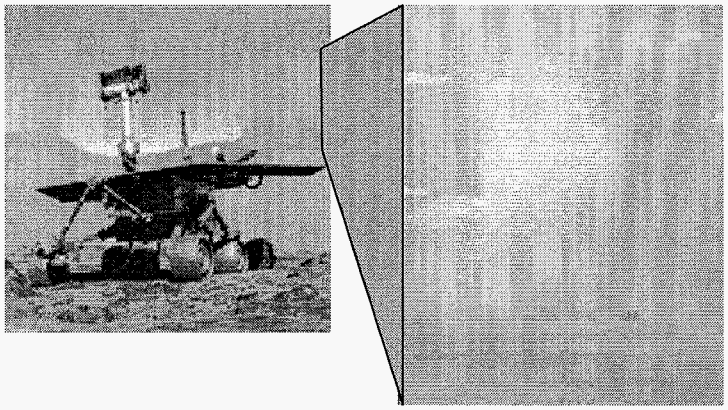
- 8Gb its at<1 Watt max,<20 0gr ams
  - Relative tot he stateo ft hea rt:
  - 8Xmo reme morype r Watt,
  - 5X morem emory perg ram

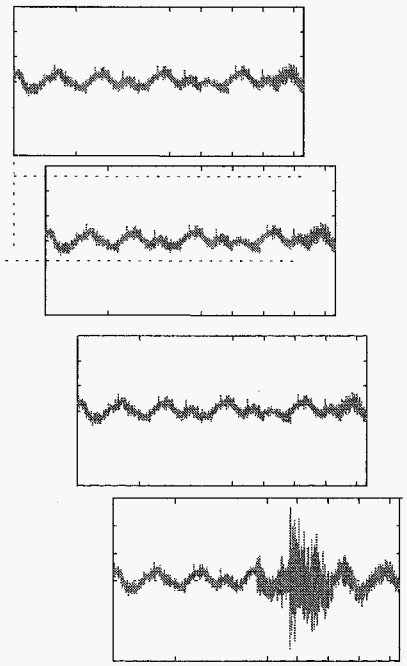
Capabilities Enabled by Advanced, Non-Volatile Memory Systems

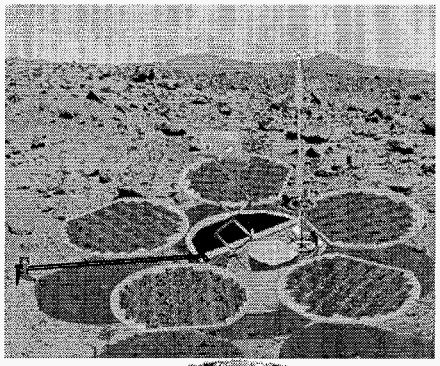
Advanced DataH andling

- Imagingf rom Moving Platforms:Ma rs ExplorationR overs
  - Largenumbe rs ofi magesar eacquiredb y then avigationcamer asa ndstor edinthe (~1 Gbit)f lashR AM
  - Only“ thumbnailsare returnedr outinely
  - Full images are retained in memory for futuredownli nk

- NetLanderSe ismology Experiment
  - Seismicdataa recol lectedconti nuously, but onlya smallfra ction ofthe se datacan be transmittedto Ear th
  - Only“synopsis ”data isr eturnedr outinely
  - Ther esti sstor edintheland er’s 8 Gbit solid stater ecorder
  - TheSEISte amr eviewst hesedata,a nd decideswhic hdatas egmentsto r eturn a fullr esolution







Conclusions

- FutureNASA spacean dEar th science missionscond uctedby JPLw illpla ce increasingde mands ons pace-basedon -board storagean dda taprocessing t echnologies.

- Advanced, high-density, low-power,rad iationt olerantmem ory systemswill be anena bling technologyform anyo f these applications.

- Compact,lo w-powers ystemsareal soe ssentialin man y future space-basedap plications