International Cooperation and The Next Fifty Years In Space Science

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The first 50 years

- V-2's from White Sands in the 1946-1952 period: first UV, X-ray astronomy.
- The IGY of 1957-58: early steps in solar-terrestrial and auroral physics
- Early satellites of the 1960s: proof of concept (Explorer, DS, Ariel, OSO, OAO; Mariner, Surveyor, 2MV, E-6).
- Real work in the 1970s and 1980s (IUE, COS-B, Einstein, ISEE; Pioneer, Viking, Voyager)
- Sophisticated international systems of the 1990s (Great Observatories, SOHO/Cluster; Galileo, Ulysses, Cassini/Huygens)

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What do scientists do in space?

- Astronomy: color vision (radio to gamma-ray), resolution and dark skies.
- Space physics: in situ measurement of particles and fields; imaging of e.g. auroral emissions; active modification experiments
- Basic physics: e.g. maser work; Gravity Probe B.
- Atmospheric science, oceanography, geophysics: imaging, remote sensing and sounding of the atmosphere and surface of Earth and others... Comparative planetology.
- Microgravity, radiation exposure and vacuum science: using space as your lab
- Life sciences: the biosphere meets the exosphere

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The next 50 years: our tasks

- Slower, larger, heavier:
- some science has a basic need for big, heavy, long-lasting facilities. Small Explorers are wonderful, but there are plenty of questions they just can't answer.
- Example: X-ray imaging. Chandra has shown the need for high resolution (arcsecond) images. But it is only a 15-cm telescope (effective aperture)! We need a Keck-class X-ray imager, and physics implies this will be heavy (but may be a constellation like Con-X and use XEUS multi-spacecraft approach)

- Many, many, many:
- For in situ science (magnetosphere), small is beautiful but want ubiquitious clouds of probes. Challenges in telemetry and control; hierarchies of nanosatellites?
- International approach crucial

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The next 50 years: what and where

- Science has moved from LEO to HEO (Chandra, ISO, XMM, Cluster) to L2 (MAP, Planck, Con-X) and solar (SIRTF): where next?
- Interferometric telescopes and constellations will be the cutting edge: TPF and TPI; Con-X/XEUS successors
- Radio astronomy will move to lunar shadow and beyond
- Space physics will move throughout the inner solar system
- More emphasis on basic physics: eg ESA's Hyper mission, more big bang studies
- More emphasis on facility-class observatories
- Integration of international mission selection? But competition is valuable...

The next 50 years: why

EXTREME PHYSICS

- Exploring general relativity and particle physics
- Physics of plasmas
- Mapping the big bang and the galaxy formation era: searching for the first stars
- Gravity waves from black holes and the early universe
- Supermassive black holes: Imaging the inner cores of quasars

PLANETS AND LIFE

- Extrasolar planets and the search for habitable ones
- Galactic ecology
- Starspots and flares: when good suns go bad
- Interstellar medium and nearby stars

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The next 50 years: the solar system

- Extend the LEO infrastructure to deep space: communications, tracking, GPS
- Normalizing the inner solar system: space weather and solar monitoring, NEO surveys and visits
- Mars: from survey to resource use
- The outer moons: Europa submarine, Titan rovers, and more
- What's in the Kuiper Belt?
- On to the stars

What about the Humans?

- Many in the science community are still skeptical of the value-for-money of astronauts for SCIENCE in space
- BUT, many of us also support human EXPLORATION and ultimately SETTLEMENT as a crucial and valuable human activity
- Just don't take it out of our little science budget!!
- Science will benefit greatly once the human infrastructure is already there for other reasons
- Many ordinary people want to live in the 'Star Trek future' and would support modest expenditure on human space-flight.
- We must build grass roots and international support for the human exploration of the Solar System. The days of presidential leadership-from-above and justification by cold-war patriotic rivalry are over.
- I speculate that serious funding for human lunar or Mars missions will begin no sooner than the 2015-2025 decade, with the first voyages a decade later.
- If there isn't an international base on the Moon or Mars by 2050, we have not done our jobs right!

2001	HESSI	LEO	X-ray solar	Solar physics
2001	MAP	L2	1.4m microwave	Big Bang mapping
2001	Genesis	L1		Solar wind collection
2001	ACS	LEO		New HST camera
2002	GALEX	LEO	0.5m UV	Survey of galaxies
2002	CHIPS	LEO	EUV detector	Local interstellar cloud study
2002	SIRTF	Solar	0.9m IR/FIR	IR observatory
2002	INTEGRAL	HEO	Gamma ray	Gamma source studies
2002	GP-B	LEO		Gravitomagnetism
2003	SWIFT	LEO	0.4m X-ray	Gamma burst studies
2003	COS/WFC-3	LEO		New HST instruments
2003?	Astro E2	LEO	4 x 0.4m X-ray	XR observatory
2003	AMS	Station		Particle physics
2004	FAME	GEO	0.6m opt	Star catalog
2005	Solar B	LEO	0.5m opt, X-ray	Solar physics
2005?	Astro F	LEO	0.7m FIR	IR sky survey
2005	Starlight	Solar	Interferometer	Interferometer test
2006	SIM	Solar	Interferometer	Interferometer
2006	GLAST	LEO	Gamma ray	Gamma source studies
2006	SMART-2	Solar?		LISA test package
2007	Planck	L2	1.5m microwave	Big Bang mapping
2007	Herschel	L2	3.5m FIR	IR observatory
2008	Eddington	L2	1.2m optical	Planet transits, stellar physi
2008?	NGST	L2	6-m IR	IR observatory
2010?	HYPER	LEO	Atomic gyro	Gravitomagnetic map
2010s	STEP	LEO		Equivalence principle
2010s	Con-X	L2	4 x 1.3m X-ray	XR observatory
2010s	SPECS test		Submm interferometer test	
2010s	EXIST	LEO	Hard X-ray	Sky survey
2010s	LISA	Solar	GW detector	Gravitational waves
2010s	ARISE	HEO	Radio	Radio observatory
2010s	XEUS 1	LEO	5-m X-ray	XR observatory
2010s	TPF	Solar?	4 x 3.5m IR	Finding Earthlike planets
2010s	Darwin	L2	6 x 1m IR	Study of Earthlike planets
2012	GAIA	L2	2 x 1.7m optical	Finding stars and planets
2020?	XEUS 2	LEO	10-m X-ray	XR observatory 4"
2020s?	SPECS Submillimeter interferometer;			X-ray Interferometer
2020s?	Interstellar Probe; Europa Submarine			
2020s?	Life Finder			Spectra of Earthlike planets
2030s?	Planet Imager		6 x 8m?	Imaging Earthlike planets

2002	MUSES C	(10302) 1989ML	Return 2006	ISAS
2002	Lunar A	Moon		ISAS
2002	Contour	Comets	Done 2008	NASA Discovery
2003?	Selene	Moon		ISAS
2003	MER 1	Mars		NASA Mars
2003	MER 2	Mars		NASA Mars
2003	Mars Express	Mars		ESA
2003	Rosetta	46P/Wirtanen	Arrive 2011	ESA CS
2004	Messenger	Mercury		NASA Discovery
2004	Deep Impact	P/Tempel-1		NASA Discovery
2007	Solar Probe	Solar (3 R-sun)		NASA study
2007?	Solar Orbiter	Solar		ESA FM
2009	BepiColombo	Mercury		ESA CS
2010?	Europa Orbiter	Europa		NASA OPP
2010s?	Dawn	Asteroid orbiter		NASA Discovery?
2010s?	Europa Lander	Europa		NASA OPP