AN HISTORICAL SUMMARY AND PROSPECTS FOR THE FUTURE OF SPACECRAFT BATTERIES

JPL

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OUTLINE

HISTORICAL EVOLUTION OF BATTERIES IN SPACE

EVOLUTION AND STATUS OF NI-CD AND NI-H_2

PRESENT APPLICATIONS

FUTURE APPLICATIONS

ADVANCED BATTERIES FOR FUTURE MISSIONS

HISTORY OF BATTERIES IN SPACE

APPLICATIONS - FIRST SPACE MISSIONS

1955			
	10/4/57	SPUTNIK 1 W FOR 3 WEEKS	Ag/Zn
	12/6/57	VANGUARD	Zn/HgO
	2/1/58	EXPLORER 1 VAN ALLEN RAD BELT	Zn/HgO
	8/7/59	EXPLORER 6 FIRST EARTH PHOTOS	Cyl Ni/Cd
1960			
	'61-64	RANGERS MOON PHOTOS	Pris Ni/Cd
	4/26/62	ARIEL I First LEO MISSION	Pris Ni/Cd
	6/23/63	SYNCOM-2 First GEO	Cyl Ni/Cd
1965	5/20/65	APOLLO CM LTD CYCLE LIFE	Ag/Zn

APPLICATIONS - FIRST SPACE MISSIONS

1970

3/13/71	IMP 1	Ag/Cd
	NON-MAGNETIC	
6/23/77	NTS-2	Ni/H_2
	12 HOUR POLAR	
9/23/77	AF	Ni/H_2
	LEO	

1980

2/14/80	SOLAR MAX	Ni/Cd
	STANDARD BATTERY	
5/19/83	INTELSAT V	Ni/H_2
	GEO	
4/4/83	STS-3	Li-BCX
	ASTRONAUT EQUIPMENT	
4/7/84	LDEF	LITHIUM & OTHERS
	EXPOSURE TO SPACE	
10/18/89	GALILEO HOURS	$Li/SO_{2/}$
	WITH THERMAL BATTERY	
	FOR JUPITER PROBE	

1990

APPLICATIONS - FIRST SPACE MISSIONS

1990	4/25/90	HST NASA LEO	Ni/H_2
	6/10/90	LEASAT Super NI/Cd	GEO
	1/25/94	CLEMENTINE LUNAR MAPPING	SPV Ni/H_2
	1/25/94	TUBSAT-B STORE MESSAGES	2 Cell CPV
1995	5/1995	CENTAUR 28V, 250AH	$Li-SOCl_2$ LAUNCH VEHICLE
	5/5/97	IRIDIUM-1 LEO 34 TO DATE	50Ah SPV
	NOV 97	FLIGHT EXP WAKESHIELD	Na/S
2000			

EVOLUTION OF NI-CD BATTERIES IN SPACE

NI-CD SPACE BATTERY EVOLUTION

	1958-69	1970-79	1980-89	1990-97
Technology	3-6 Ah Cells Pellon GTM Seals	5-20 Ah Cells Teflonation Ceramic Seals NASA Std Cells	NASA 50 Ah E-I Process Lt Wt Designs Passivation	Super Ni-Cds Pellon 2536
Performance	2-5% DOD < 1000 cycles Leaks Const. I Charge	10-20% DOD NASA VT	>10 Years GEO 40K Cycles LEO	'MATURE'
Manufacturers	Gould Gulton Saft Sonotone	EPI G.E.. Gulton Saft	EPI G.E../Gates Saft Sanyo	EPI Hughes Saft Sanyo Acme

EVOLUTION OF NI-H_2 BATTERIES IN SPACE

NI-H_2 SPACE BATTERY EVOLUTION

	1958-69	1970-79	1980-89	1990-97
Technology		35-50 Ah IPV E-I Aq. Process Back to Back(C) Recirculating(AF)	E-I Alc. Process 100 Ah	CPV & SPV 120 Ah 26% KOH
Performance		LEO 25% DOD 2000 Cycles Polar 40% DOD 5 years	40K Cycles LEO 10 YEARS GEO	50-100K LEO CYCLES
Manufacturers		EPI Yardney ERC SAFT GE	EPI Hughes JCI Saft Gates	EPI Hughes JCI Saft

KEY EVENTS IN SPACE BATTERY HISTORY

	1958-69	1970-79	1980-89	1990-97
NI-CD	'59 EXPLORER-6 (CYLINDRICAL) '62 ARIEL-1 LEO (PRISMATIC) '63 SYNCOM2 GEO		'80 SOLAR MAX NASA 20 AH STD '82 LANDSAT -D STD 50 Ah	'90 LEASAT GEO SUPER NI-CD
NI-H_2		'77 NTS-2 & AF FIRST IPV USE	INTELSAT 5 IPV GEO	'90 HUBBLE IPV '94 CLEMENTINE SPV '94 TUBSAT CPV
LITHIUM			'83 STS- LI-BCX '89 GALILEO Li-SO_2	'95 CENTAUR '96 PATHFINDER

NASA MISSIONS TODAY

NEAR TERM NASA MISSIONS - GSFC

LAUNCH DATE	MISSION NAME	MISSION TYPE	NO. BATS	NO CELLS/BAT	CELL CAPACITY	CELL TYPE
11/97	TRMM	LEO	2	22	50Ah	EPI-SUPER NI-CD
12/97	TRACE/SMEX	LEO/SS	1	22	9Ah	EPI- SUPER NI-CD
?/97	ACE	LIBATION	1	18	12Ah	NI-CD
5/98	LANDSAT-7	LEO	2	17	50Ah	EPI - AXIAL Ni-H_2
6/98	EOS-AM	LEO	2	54	50Ah	EPI-RE Ni-H_2
7/98	GOES-L	GEO	2	28	12Ah	GATES / SAFT NI-CD
9/98	WIRE/SMEX	LEO	1	22	9Ah	EPI-SUPER NI-CD
?/99	IMAGE	LEO	1	22	21Ah	CS SUPER NI-CD
?/00	MAP	FULL SUN	1	11/2CELL	23Ah	CPV EPI-J RE NI-H_2

NEAR TERM NASA MISSIONS - JPL

LAUNCH DATE	MISSION NAME	MISSION TYPE	NO. BATS	NO CELLS/BAT	CELL CAPACITY	CELL TYPE
1996	MGS	MARS ORB	2	11/2CELL	23Ah	CPV EPI-J RE NI-H_2
1996	MPF	LANDER	1	18	40Ah	AG/ZN RECHARGE
1996	MPF	ROVER	3	3	12Ah	LI-$SOCL_2$ 'D'
1997	CASSINI PROBE		3	13	8Ah	LI-SO_2
1998	NEW MIL DS-1		1	11/2CELL	12Ah	SAME AS MSTI-3
1998	NEW MIL DS-2		2	4	2Ah	LI-$SOCL_2$ FLAT PLATE
1998	MARS SURVEYOR/98		2	11/2CELL	16Ah	NI-H_2
1999	STARDUST		2	11/2CELL	16Ah	NI-H_2
1999	STARDUST SAMP. RET		3	13	8AH	LI-SO_2

NEAR TERM NASA MISSIONS - MSFC

LAUNCH DATE	MISSION NAME	MISSION TYPE	NO. BATS	NO CELLS/BAT	CELL CAPACITY	CELL TYPE
1998	AXAF	LEO	3	22 CELLS	40 Ah	EPI IPV NI-H_2

THE FUTURE OF BATTERIES IN SPACE

POTENTIAL NASA SPACE MISSIONS / APPLICATIONS

NASA MISSIONS

JPL

- MARS LANDER AND ROVER -2001
- MARS LANDER AND ROVER -2003
- MARS SAMPLE RETURN MISSION - 2005
- CHAMPOLION MISSION - 2003
- SOLAR PROBE - 2005

GSFC

- SATELLITE SERVICING TOOLS
- LIBATION POINT SPACRAFT (MAP-2000,NGST 2007)
- GEO SPACECRAFT(GOES)
- LEO SPACECRAFT(EOS)

JSC

- SHUTTLE APPLICATIONS

AIR FORCE MISSIONS

LEO

- NPOESS -2007
- Surveill. Platforms
- SBIRS Low

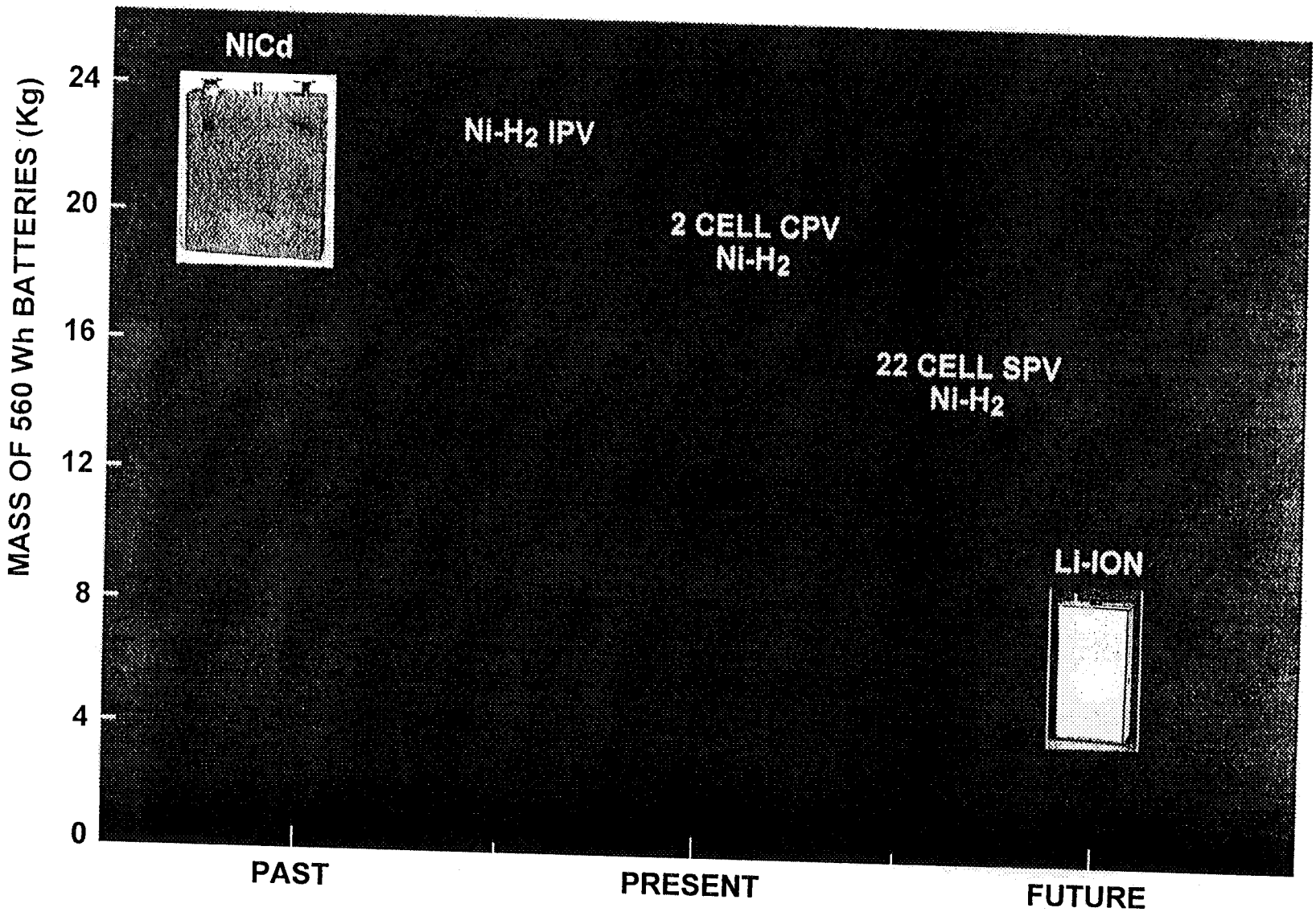
GEO

- Milsatcom - 2002
- DSP

AIRCRAFT

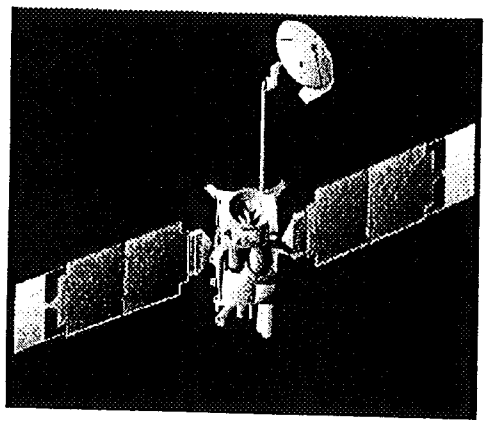
- AVIATION 2001
- UAVs- 2002

EVOLUTION OF FLIGHT BATTERIES

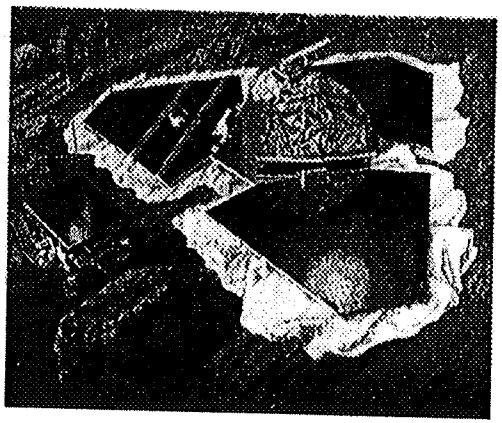


POTENTIAL NASA APPLICATIONS

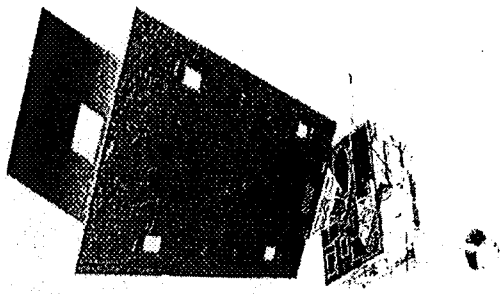
Planetary Orbiters



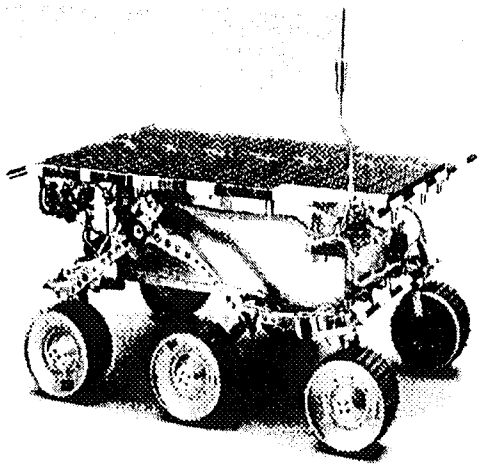
Planetary Lander



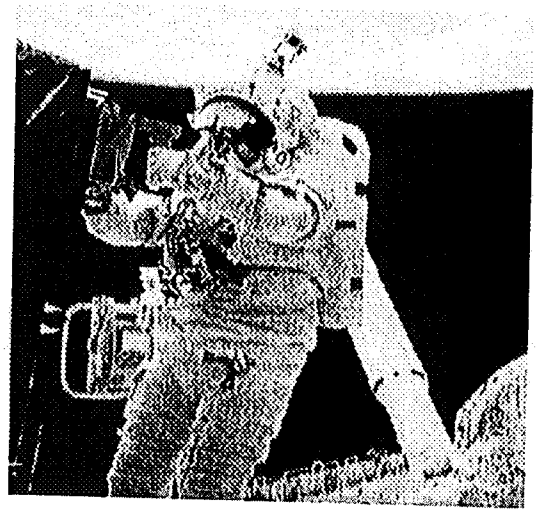
GEO Spacecraft



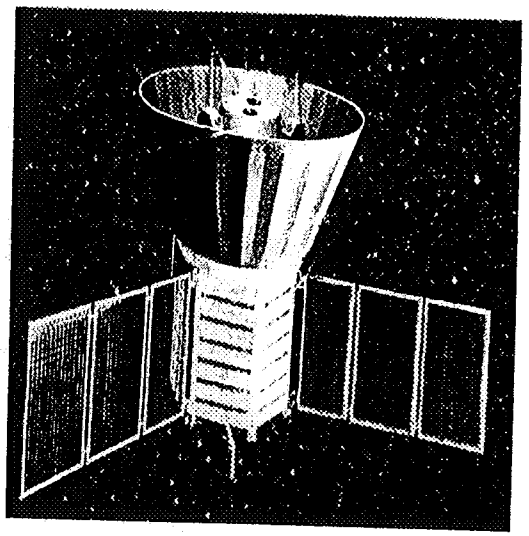
Planetary Rover



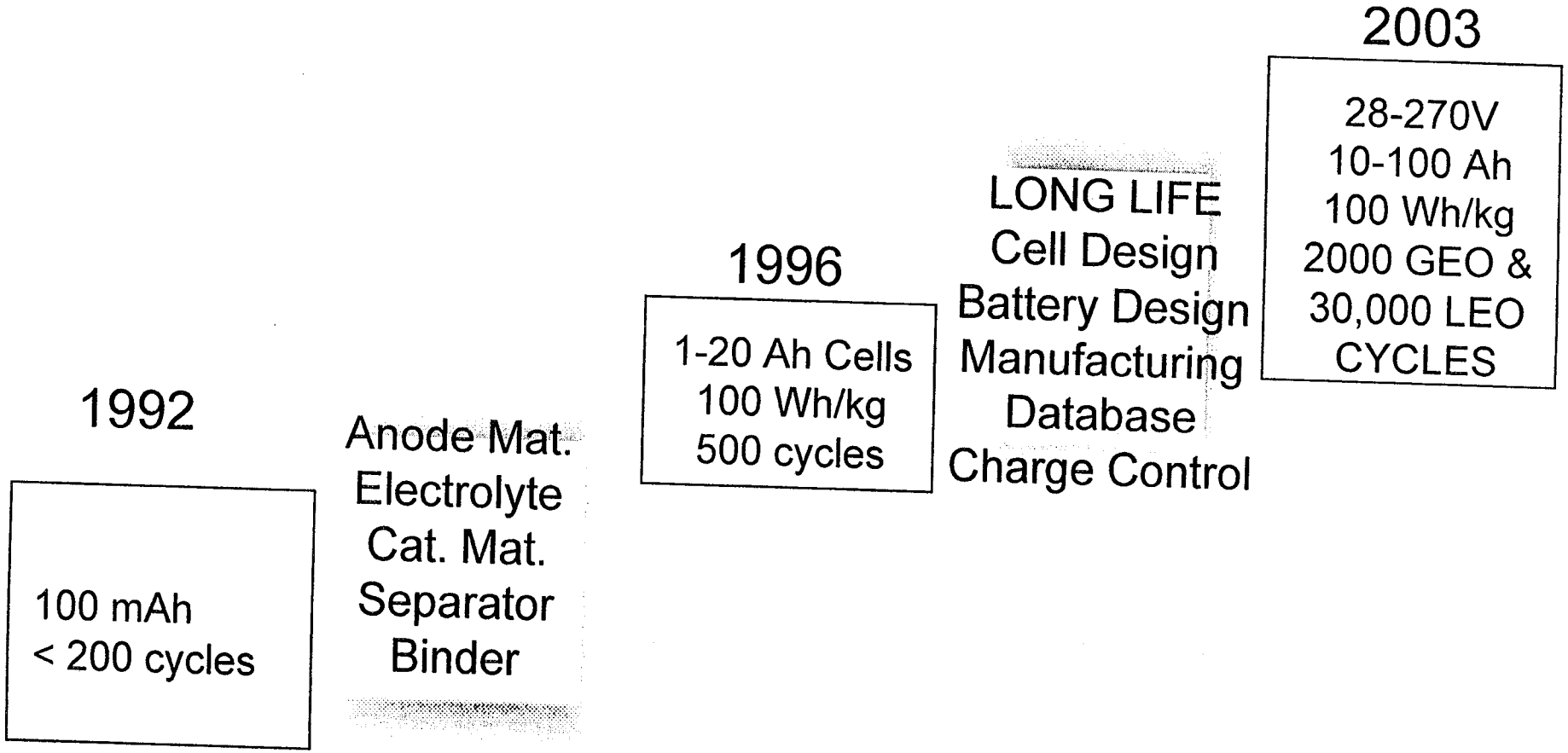
Astronaut Equipment



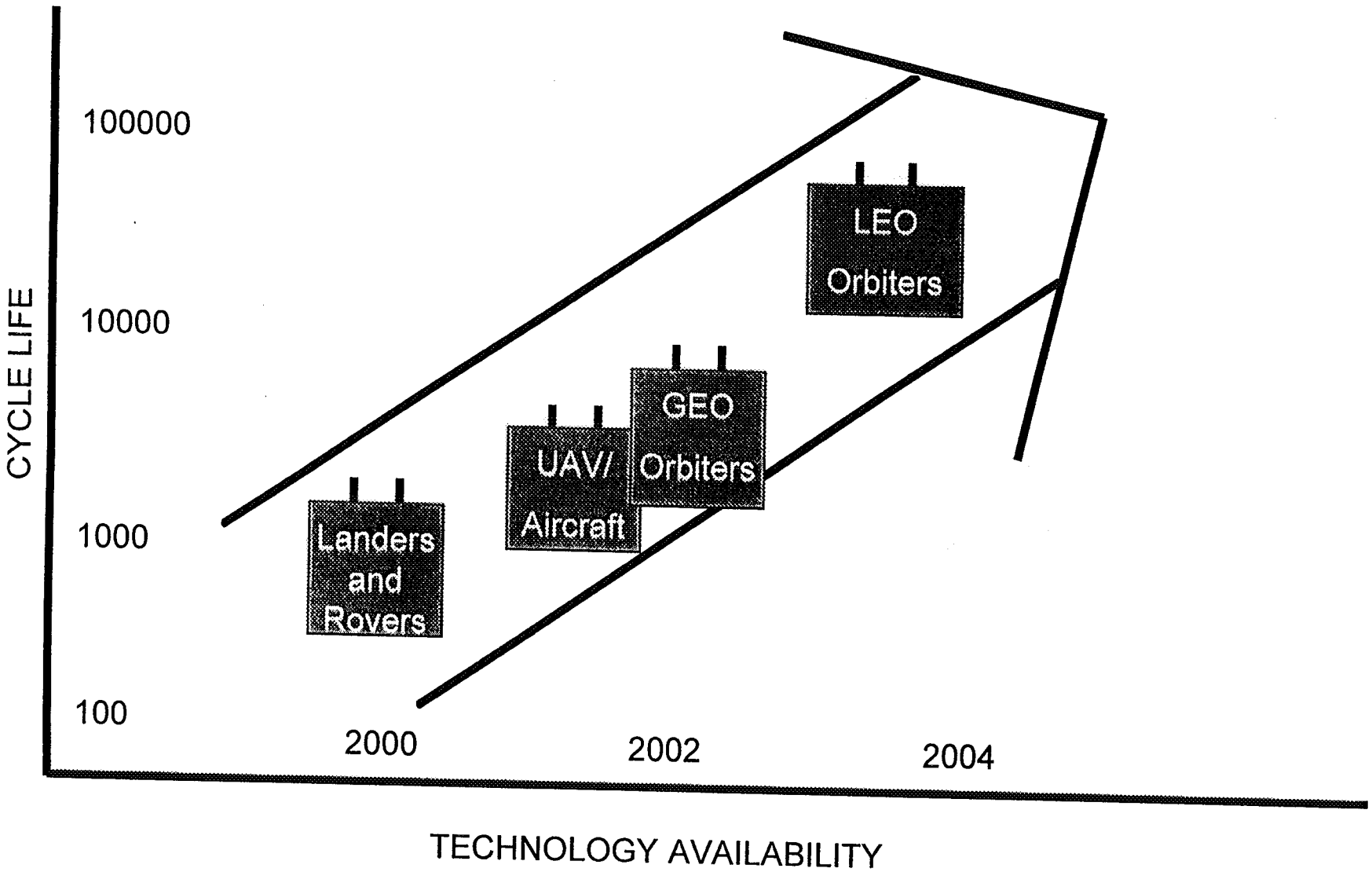
LEO Spacecraft



TECHNOLOGY PROGRESSION



TECHNOLOGY DEMONSTRATION MILESTONES



PROGRAM OBJECTIVES OF NASA / AF LI-ION PROGRAM

- DEVELOP ADVANCED LITHIUM ION CELLS AND SMART BATTERIES FOR AEROSPACE AND DOD APPLICATIONS
- ESTABLISH U.S. PRODUCTION SOURCES
- DEMONSTRATE TECHNOLOGY READINESS FOR:
  - SATELLITE SERVICING TOOLS BY 1999
  - ROVERS AND LANDERS BY 2000
  - LIBATION POINT MISSIONS BY 2000
  - GEO MISSIONS BY 2001
  - MILITARY TERRESTRIAL APPLICATIONS BY 2001
  - LEO MISSIONS BY 2003

TECHNOLOGY CHOICES FOR FUTURE MISSIONS

NEAR TERM (>2000):

LI-ION LIQUID ORGANIC ELECTROLYTE CELLS

- 1-20Ah CELL SIZES
- >1000 CYCLES
- SUPERIOR LOW TEMPERATURE PERFORMANCE
- COMMERCIAL APPLICATIONS USE
- LEVERAGE OF FUNDS SEVERAL PROGRAMS

LONG TERM MISSIONS (>2007)

LI - ION POLYMER

- HIGHER SPECIFIC ENERGY
- ADAPTABILITY TO SEVERAL CONFIGURATIONS

TECHNOLOGY APPROACH TO NASA / AF LI-ION PROGRAM

DEVELOP ADVANCED ELECTRODE MATERIALS AND ELECTROLYTES TO ACHIEVE IMPROVED LOW TEMP. PERFORMANCE AND LONG CYCLE LIFE

OPTIMIZE CELL DESIGN TO IMPROVE SPEC. ENERGY, CYCLE LIFE AND SAFETY

ESTABLISH MANUFACTURING PROCESSES TO ENSURE PREDICTABLE PERFORMANCE

DEVELOP AEROSPACE LITHIUM ION CELLS IN 10, 20, 50, AND 200 AH SIZES

DEVELOP BATTERIES IN 28, 100 AND 270 V CONFIGURATIONS

DEVELOP ELECTRONICS FOR SMART BATTERY MANAGEMENT

DEVELOP A PERFORMANCE DATABASE FOR VARIOUS APPLICATIONS

DEMONSTRATE TECHNOLOGY READINESS FOR VARIOUS NASA AND AIR FORCE MISSIONS

SUMMARY

THIS PAPER INCLUDED:

A CHRONOLOGICAL HISTORY OF BATTERY FLIGHT FROM 1959 TO THE PRESENT

A LIST OF THE NEAR TERM FLIGHT MISSIONS FROM 1997-2000

A PLAN FOR AN INTERAGENCY (NASA / AF) PROGRAM TO DEVELOP LI-ION BATTERIES FOR PLANETARY, AVIATION, LEO AND GEO MISSIONS FROM 2000-2003