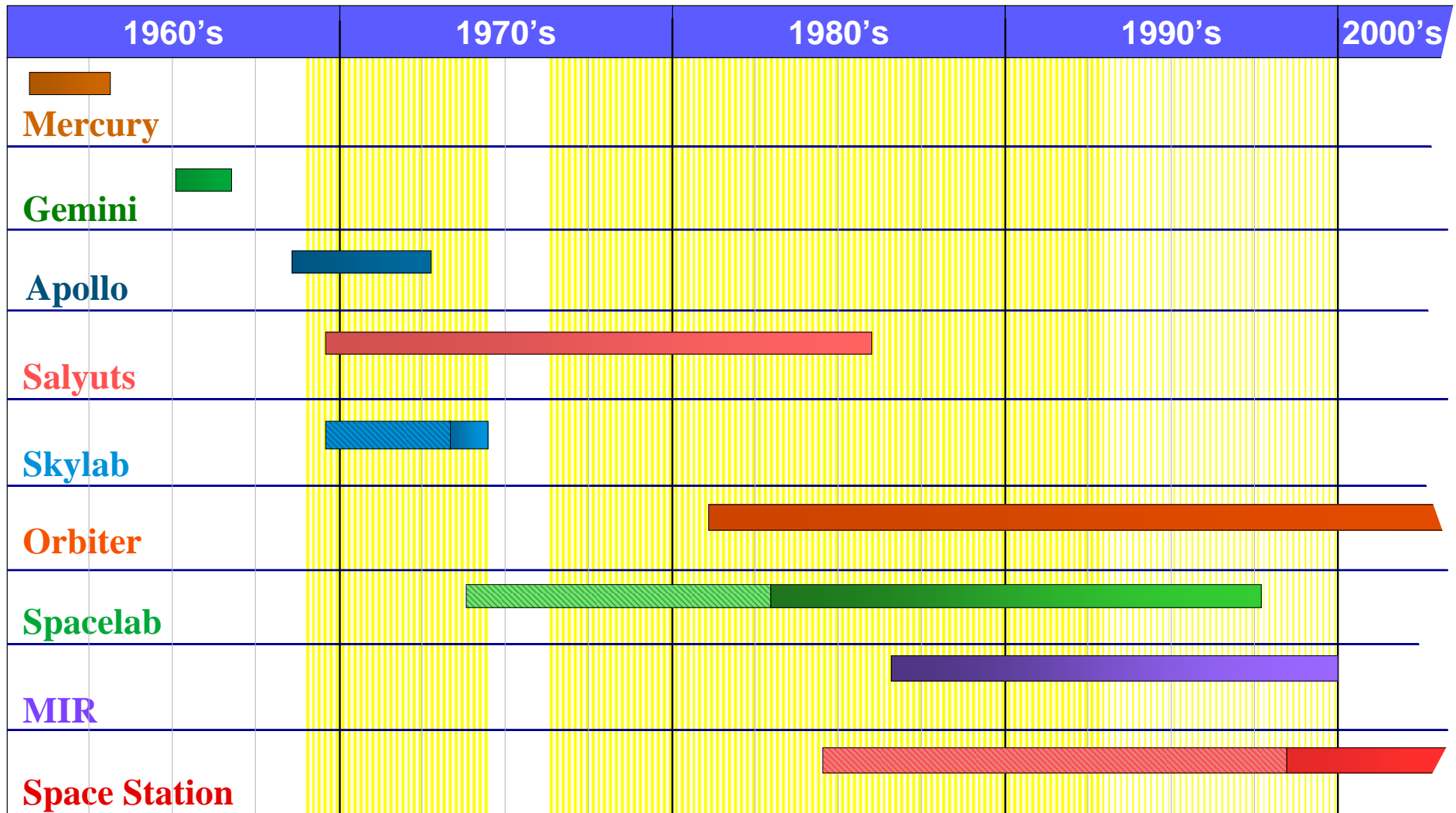


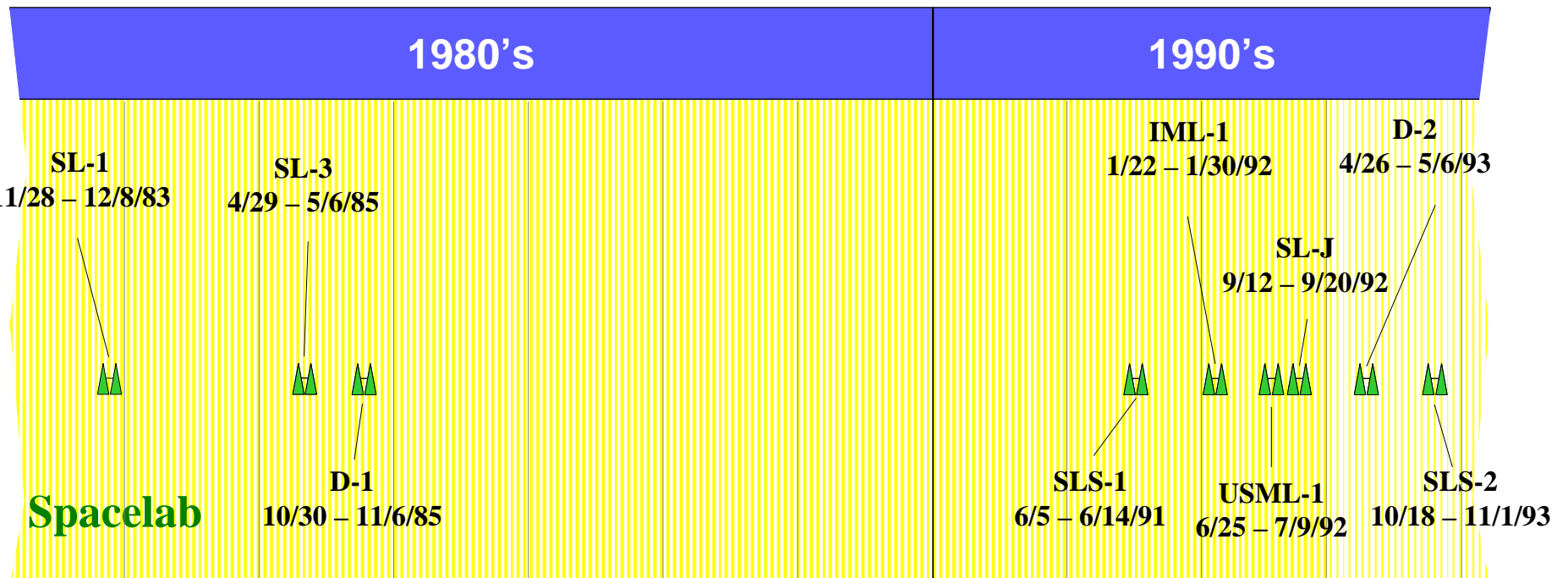


A History of Manned Space Systems



-  - Time Periods addressed by Humphries
-  - U.S. pre-flight development phase

A History of Manned Space Systems (Excerpt)



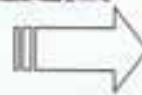
 - Time Periods addressed by Humphries

ECLSS Chronology (Systems Excerpt)

Function	Mercury	Gemini	Apollo (CSM/LEM)	Early Russian (typical) Salyut /Soyuz	Skylab	Orbiter	MIR	Spacelab	Early Space Station (ref 5 & 6)
Crew size	1 man	2 man	3/2 man	2-4/3	3 man	2 –7 man	3(2-6)	3 persons (6 for 24/7 continuous manning)	3-4 persons initially (8 planned later at PMC)
Mission Design (actual length) life	TBD(2) days	14 (14) days	14 (11) days/ 2 (2) days	TBD (15 days (Salyut-3) –816 days (Salyut-7))4.2 days flight+ 6 months docked to ISS	(167 days=(28+56 + 83 manned days)+ 5 days launch to 1 st manning and two unmanned period of 36 and 52 days, respectively, for a total flight program time of 260 days)	TBD (8-9 days typical) (16 day EDO capability), multi-mission life with post mission refurb	15 (10 years, short 8 days To 23 March 2001)	Same as orbiter— multi-mission life with post-missions refurb. Longest mission LMS, 2 hours short of 17 days.	Initially 30 years target, later 15-20 years with 90 day resupply and 45 day safe haven. (Later, combined with US/Russian Assured Crew Return Vehicle (ACRV))
Manned Volume	1.56 m3	2.26 m3	5.9 m3/6.65 m3	TBD/9 m3	361 m3	74 m3	TBD	68 m3+tunnel	Approx. 1218 m3 with 6 modules
Total Manned Volume Pressure	5 psia	5 psia	5/5 psia	TBD/14.7	5 psia (leakdown to 2 psia allowed during unmanned periods)	14.7 psia	14.7	14.7 psia	14.7 psia
Atmospheric Constituency	100% O2	100% O2	Ambient atmosphere at launch to oxygen rich with time/5 psia oxygen	21% O2/ 79% N2	2.8 psia O2 and 2.2psia N2, some early purge cycling	21% O2 and 79% N2	21% O2/ 79% N2	21% O2 79% N2	21% O2 79% N2
Special Air Cooling and Fluid Services	Subsystem equipment	Subsystem equipment	Subsystem equipment, EVA and limited crew support	Subsystems + Crew services + airlock/EVA support	Experiment and subsystems equipment cooling and Airlock/EVAs, as well as crew services support	Experiment and subsystems cooling , EVA support and crew services support	Sub-systems + Crew services ,Airlock /EVA support +TBD	Experiment and subsystems equipment cooling and special payload services fluid support	Experiment and subsystems equipment cooling and special payload service fluid support as well as Airlock/EVA and crew services support

MSFC/Boeing test facility History

MSFC Building 4755 in 1989-1992 for Comparative Testing of ECLSS Technologies for Space Station Freedom Program



MSFC Building 4755 in 2004 for International Space Station ECLSS/Thermal Test Beds



ECLSS Major Closure Subsystem Selections (about 92/93)

Overall Closure Area	Assemblies/ Functions	Competing Hardware (see ref 1 & 2) (typically 4 person units)	Advantage	Disadvantage
Air loop(s)				
	CO2 removal			
		4 Bed Mole sieve (4BMS)	Basic material experience, Flight proven concept, risk	Weight/power/volume (Wpv)
		2 Bed Mole Sieve (2BMS)	Flight unit experience, proven reliability	mass loss makeup
		Solid Amine Water Desorbed (SAWD)	Wpv? (w/o systems integration issues understood)	Steam generator desorption and pressurized steam reqmt, complication/integration/reliability, moisture load, amine life/stability/moisture separation, funding for continued testing.
		Electro-chemical Depolarized Concentrator (EDC)	Wpv? (w/o systems integration of independent H2 supply understood)	Safety (requires independent hydrogen to function), Integration of hydrogen handing complication/unknown integration penalties, system resources impact, reliability, funding for continued testing
	CO2 reduction			
		Bosch*	Complete loop closure, Wpv	handling/size of waste carbon canister/flight experience, air purging capability required
		Sabatier	Ground test reliability, min planned maintenance	Flight experience
	O2 Generation			
		Static Feed Water Electrolysis (SFWES)	Slight Wpv	Water feed concerns, ground test reliability
		Solid Polymer Electrolysis (SPE)**	Similar technology to used in submarines	Technology readiness for space flight unit (multi-stack cell drying at the time)

ECLSS Major Closure Subsystem Selections (about 92/93) Cont'd

Overall Closure Area	Assemblies/ Functions	Competing Hardware (see ref 1 & 2) (typically 4 person units)	Advantage	Disadvantage
Water loop(s)				
	Hygiene/potable water recovery			
		Reverse Osmosis (RO)*	Wpv	Up-Mass, Reliability, 1-g testing problems, soap clogging, low recovery efficiency, brine membrane fouling
		Multifiltration (MF)	Ground test results, Simplicity	Up-Mass Requirements still significant, soap fouling
	Urine Water Recovery			
		Thermo-electric Membrane Evacuation System (TIMES)*	Weight/volume. Primarily made-up of non-moving parts	1-g testing problems, urea membrane fouling, throughput limits, reliability, technology readiness
		Vapor Compression Distillation (VCD), power	Ground test results. Artificial -g creation (1-g tests more flight representative). Power.	Technology readiness, many moving (TBD reliability) parts, recovery efficiency

Selections as of 92/93 timeframe (ref 2)

* Baselined earlier, late 80s

** Later, Final selection

shortage of program funds forced an early decision in CO2 selection testing in late 80s

References:

1. "The Space Station Air Revitalization Subsystem Design Concept" by C.D. Ray, K. Y. Ogle, R.W. Tipps, R.L. Carrasquillo, and P. Wieland
2. "Space Station Freedom Environmental Control and Life Support System Regenerative Subsystem Selection" by R.L. Carrasquillo, D.L. Carter, D.W. Holder Jr, C.F. McGriff and K. Y. Ogle

Life Support Systems Major flight Anomalies

- Skylab--none
- Spacelab--none

Major Observations/Lessons Learned

(6 of 30)

- General:
 - In-depth Planning— key! Work scope understanding (detailed CS (contractor tasking)), process and manpower burden understanding — informal internal signoffs/interface agreements—advertise, especially within team.
 - Integration (esp. horizontal) with other disciplines and specialties is major task often underestimated — layout in detail—suggest NxN charts as starting point—Define configuration & make it a living document and communicate continually.
 - Essential to establish a Design/System Engineer (D/SE)s for major subsystem assemblies. Keep a living log of configuration and design change rationales. Make someone responsible for everything!
 - You can't test every possible condition. Build models for important subsystems-- be sure you have simple and detailed version capabilities. Start early. Verify models by tests-- ID uncertainty areas and analyzed off-nominals/dispersions.

Major Observations/Lessons Learned (continued)

- Safety (as well as reliability/operability) is the ECLSS D/SE and individual team member responsibility (don't think of it as a separate (S&MA) safety engineer's responsibility.)
- Reliability/Operability —Fleet leader testing that begins early and includes flight based data is essential—especially true for interplanetary flights and habitats. --Test! Test! Test! If possible, include a good ECLSS handyman-astronaut that is well trained and has a proper toolkit.