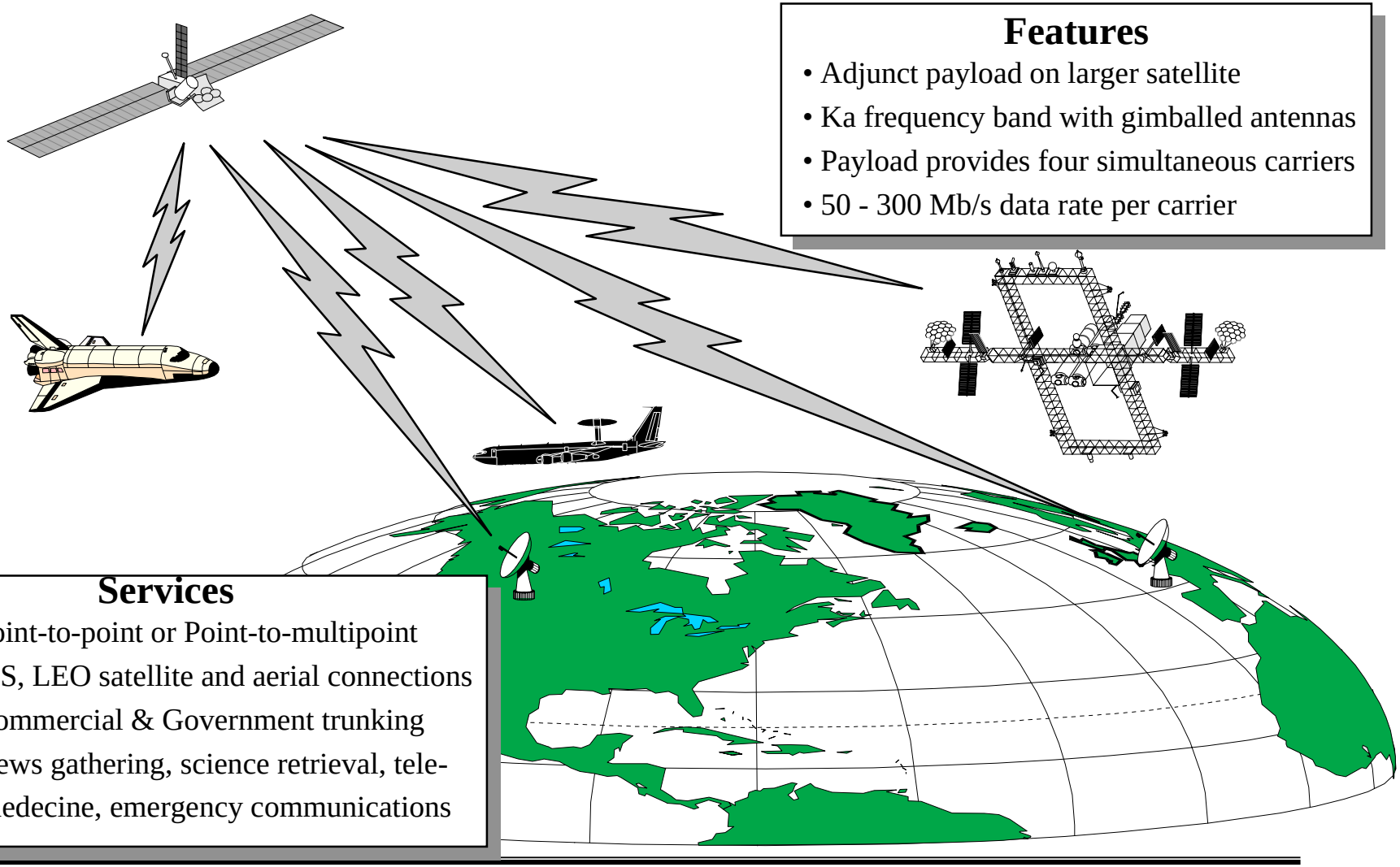
Adjunct Payload
for
ISS High-Rate Communications

W. Carl Mitchell, Robert Cleave, and David Ford
Presented by Carl Mitchell

Adjunct Payload Architectural Concept



Features

- Adjunct payload on larger satellite
- Ka frequency band with gimballed antennas
- Payload provides four simultaneous carriers
- 50 - 300 Mb/s data rate per carrier

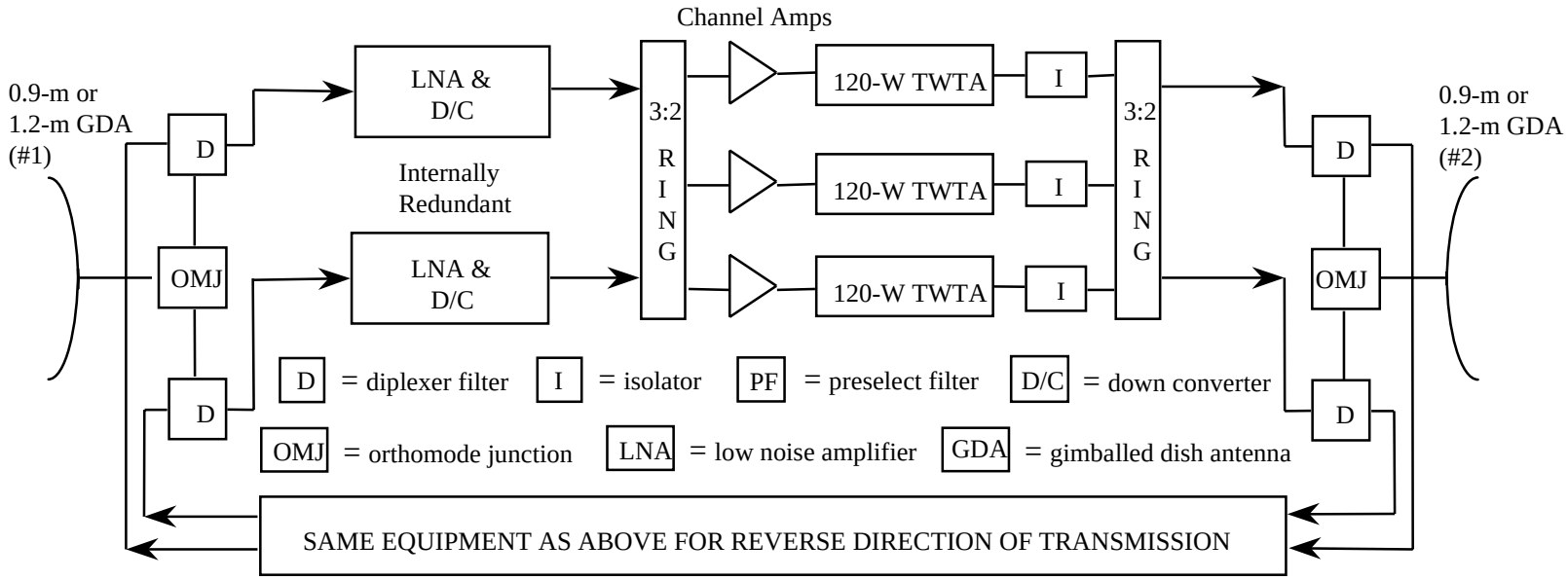
Services

- Point-to-point or Point-to-multipoint
- ISS, LEO satellite and aerial connections
- Commercial & Government trunking
- News gathering, science retrieval, tele-medecine, emergency communications

Estimated Data Rates

- ISS: 50 to 300 Mb/s near term
  Up to 1 Gb/s far term
- LEOs: Up to 300 Mb/s near term
- UAVs: Up to 300 Mb/s near term
- Trunking: 10 to 155 Mb/s (OC-3)
- Point-to-multipoint: Up to 100 Mb/s
- News gathering, etc: Up to 10 Mb/s or More

Adjunct Payload Block Diagram



Slightly different circuitry would allow combining the outputs of any two of the three TWTAs to obtain - 235 W amplifier.

Link Budget Assumptions

- Two-carrier, Dual polarization operation
- QPSK, rate 7/8ths R-S coding, 10^{-5} BER
- 3 dB end-to-end margin, 20° path elev. angle
- External C/I = 18 dB
- Per-link antenna contribution to xpol isolation = 27 dB
- 2 dB rain attenuation on uplink from UAV
- 5 dB rain attenuation on downlink from UAV and ISS (99.5% availability at Wash., D.C.)
- LNA noise figure: 1.5 dB Earth Terminal, 2.2 dB Payload

Adjunct P/L Capacity per Polarization (Mb/s)

(With 0.61-m Adjunct Payload Antenna Diameter)

Adjunct Payload Xmtr Pwr:	**120 W**	**235 W**
ISS Transmit Parameters[1]		
2-m Ant., 120 W Xmtr	75	80
2-m Ant., 235-W Xmtr	125	140
UAV Transmit Parameters[2]		
0.61-m Ant., 120-W Xmtr	15	20
0.91-m Ant., 120-W Xmtr	30	40
1.22-m Ant., 120-W Xmtr	40	55

1. End-to-end margin of 3 dB in clear weather. 9.5 to 11.5 dB of rain fade reduces margin to zero.
2. End-to-end margin of 3 dB with rain on uplink and downlink

Adjunct P/L Capacity - Single Pol. (Mb/s)

(With 0.61-m Adjunct Payload Antenna Diameter)

Adjunct Payload Xmtr Pwr:	**120 W**	**235 W**
ISS Transmit Parameters[1]		
2-m Ant., 120 W Xmtr	120	130
2-m Ant., 235-W Xmtr	205	235
UAV Transmit Parameters[2]		
0.61-m Ant., 120-W Xmtr	23	26
0.91-m Ant., 120-W Xmtr	41	51
1.22-m Ant., 120-W Xmtr	57	76

1. End-to-end margin of 3 dB in clear weather. 8.5 to 11 dB of rain fade reduces margin to zero.
2. End-to-end margin of 3 dB with rain on uplink and downlink

Adjunct P/L Capacity per Polarization (Mb/s)

(With 0.91-m Adjunct Payload Antenna Diameter)

Adjunct Payload Xmtr Pwr:	**120 W**	**235 W**
ISS Transmit Parameters[1]		
2-m Ant., 120 W Xmtr	165	180
2-m Ant., 235-W Xmtr	275	320
UAV Transmit Parameters[2]		
0.61-m Ant., 120-W Xmtr	40	45
0.91-m Ant., 120-W Xmtr	70	85
1.22-m Ant., 120-W Xmtr	90	125

1. End-to-end margin of 3 dB in clear weather. 9.5 to 11.5 dB of rain fade reduces margin to zero.
2. End-to-end margin of 3 dB with rain on uplink and downlink

Adjunct P/L Capacity per Polarization (Mb/s)

(With 1.22-m Adjunct Payload Antenna Diameter)

Adjunct Payload Xmtr Pwr:	**120 W**	**235 W**
ISS Transmit Parameters[1]		
2-m Ant., 120-W Xmtr	290	315
2-m Ant., 235 W Xmtr	495	570
UAV Transmit Parameters[2]		
0.61-m Ant., 120-W Xmtr	70	80
0.91-m Ant., 120-W Xmtr	120	150
1.22-m Ant., 120-W Xmtr	165	225

1. End-to-end margin of 3 dB in clear weather. 9.5 to 11.5 dB of rain fade reduces margin to zero.
2. End-to-end margin of 3 dB with rain on uplink and downlink

Comment on Budgets

- Throughput is “uplink” limited (i.e., ISS-to-Adjunct P/L or UAV-to-Adjunct P/L)
  - Double ISS power, 67% throughput increase
  - Double Adjunct P/L power, 9% throughput increase
  - For ISS service, 9.5 to 11.5 dB rain fade required to reduce end-to-end margin to zero

Adjunct Payload vs I-VII and I-IX

Item	Adjunct[1]	I-VII(S-1)	I-IX
Aperture diameter, m	0.9	0.9	0.85
Frequency band	Ka	Ku	Ku
EIRP, dBW EOC	+4 to +8 dB over Intelsat s/c		
G/T, dB/K EOC	+6 dB over Intelsat s/c		

1. Adjunct payload with 120-W transmitter

Mass and Power Estimates

- Adjunct payload:
  - Mass 70 kg
  - DC power 1 kW
- Fraction of typical communications payload on Loral's LS-1300 bus:
  - Mass 15%
  - DC power 15%

Industry Provides Several Different Options

Possible Business Models

	Purchasing Services	Partnering	Procuring & Operating Hardware
Financing	Private	Private/Public	Public
Operations	Private	Private	Public
Services	Leased	Preferential Lease	None
Financial Risk	Medium	Low	Medium
Technical Risk	Low	Low	Low
Market Risk	Medium	Medium	Low
Use of Commercial Frequencies	Yes	Maybe	No

Why A Partnership

- Required payload capabilities push current commercial envelope
- Uncertain commercial market for similar services
- Lower cost to Government
- No Government long-term lease (anchor tenancy) without Congressional approval

One Possible Partnership Model

- Government responsibilities
  - Interface specifications
  - Funding for adjunct payload only
    - Private industry to cover bus, launch vehicle and insurance costs
- Pricing methodology
  - Adjunct payload consumes valuable spacecraft resources
  - Like Shuttle, pricing based on the greater of:
    - Percentage mass consumed
    - Percentage power consumed
    - Percentage real estate / volume consumed

Significant Partnership Advantages For U.S. Government

- Shared financial liability & capital exposure
- Rapid response time (due to commercially-driven shortened cycles)
- Cost amortization among many users
- Use of commercial RF spectrum
- Transfer of some operational responsibility to private industry

Partnership Advantages For U.S. Industry

- Reduced market risk
- Lower capital exposure
- Commercial “spin-offs” and market seeding

ROM Lease Cost

- Representative Ku-band satellite
  - 24 36-MHz transponders, 120-W each
  - $3M approximate annual wholesale lease per transponder
- Adjunct P/L (non-preemptible, duplex, full time)
  - 15% of representative Ku-band satellite revenue
  - 0.15 x 24 x $3M = $11M per year
  - Up to 550 Mb/s relay from ISS to 6.1-m ground station
- Intelsat Ku-band spot (rates as of July 1, 1997)
  - -$0.6M/year for 5-yr lease of 18 MHz (non-preemptible, half-channel, simplex, full time service, standard power)

Adjunct P/L vs Intelsat Cost / Mb/s

- Intelsat
  - QPSK in 18 MHz, rate 7/8ths coding: - 24 Mb/s
  - $0.6M per simplex half-channel per year (need a second half channel for duplex service and then matching foreign half channels if service is to/from a non-U.S. Intelsat member)
  - $100 K per Mb/s per year (connection to non-U.S. member)
- Adjunct Payload
  - 275 Mb/s per polarization or 550 Mb/s simplex
  - 1100 Mb/s duplex
  - $11M per year cost
  - $10.0K per Mb/s per year

Conclusions

- Adjunct Payload technically feasible for near- to mid-term data rate requirements
- Uncertain and limited commercial market for these data rates
- Partnering benefits Government and industry
  - Bridges uncertainties and limitations
  - Government avoids cost of unique satcom system, including launch and operations
  - Industry entry into potential commercial market

US Government Commercial SATCOM Purchases

		Services	Partnership	Hardware Procurement
Late '60's	Experimentation and limited operations	☆		
1970's	Navy "Gapfiller" lease on Inmarsat	☆		
1970 - 90's	Navy "Leasat"		☆	
1980's	UHF Follow-on (UFO) commercially procured (D.O.O.) for 9 spacecraft			☆
	Armed Forces Radio and TV Services (AFRTS); first TVRO's on Navy ships	☆		
	Operation Desert Storm - Inmarsat for MSS, Commercial C-band, Trojan Spirit ground terminal	☆		☆
1990's	Panamsat in South America for DEA	☆		
	Inmarsat-A terminals on Navy ships	☆		☆
	Commercial Satellite Communications Initiative (CSCI)	☆		
	Global Broadcast System (GBS)			☆
	Iridium gateway in Hawaii; 2000 Iridium terminals	☆		☆
	TV - Direct to Sailors (TV-DTS)	☆		
	DISN Transmission Services - Pacific	☆		
2000	Wideband Gapfiller			☆