Unifying Spacecraft Payload Interconnects Using the Reprogrammable Space Network Interface Controller

Ian Troxel, Matthew Fehringer, AJ Roberts, and Paul Murray
SEAKR Engineering, Inc.
Centennial, CO

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Motivation

- Interconnection networks within spacecraft include mixture of disparate standards that are often custom versions for the aerospace industry
  - Buses such as Compact PCI and VME or point-to-point links such as IEEE 1394, MIL-STD-1553B, SpaceWire, RS422, etc.

- Latest commercial technology can improve performance and scalability
  - Top contenders include:
    - PCI Express with good performance but poor scalability and FT features
    - RapidIO™ with good FT features and scalability but poor device availability
    - IP/Gigabit Ethernet, a ubiquitous standard with good all around features

- Unifying disparate protocols can improve interoperability while reducing non-recurring engineering
  - Protocol independence allows designers to focus on choosing devices that meet mission objectives regardless of interconnection standard
  - Facilitates plug-and-play payload design with virtually any sensor and any other onboard processing resource able to interconnect

Ethernet Not New to Space

- Numerous IP/Ethernet-based network components moving to aerospace
  - ARINC 664 standard Avionics Full Duplex Switched Ethernet (AFDX) [1]
  - Cisco Router in Low Earth Orbit (CLEO) [2]
  - HP ProCurve™ Switch aboard the ISS Columbus module [3]
  - GSFC's Proposed IP-centric lunar communication network [4]
  - Transformational Satellite Communications System (TSAT) [5]
  - European Satellite Communication Network (SatNEx) [6]
- SEAKR's Space Gigabit Ethernet (SGE)
  - Full compatibility with IEEE 802.11 above the physical layer
  - Demonstrated with COTS switches, hubs, etc. and remote access via Internet
  - Space-qualified physical device tested to meet a range of mission specifications
  - Using custom physical protocol transparent to Ethernet MAC and above layers
  - Upcoming flight delivery for a 10-year GEO mission scheduled to launch Q2'09
- SEAKR's SGE forms the basis for the Reprogrammable Space Network Interface Card (RSNIC) payload concept

RSNIC Payload Concept

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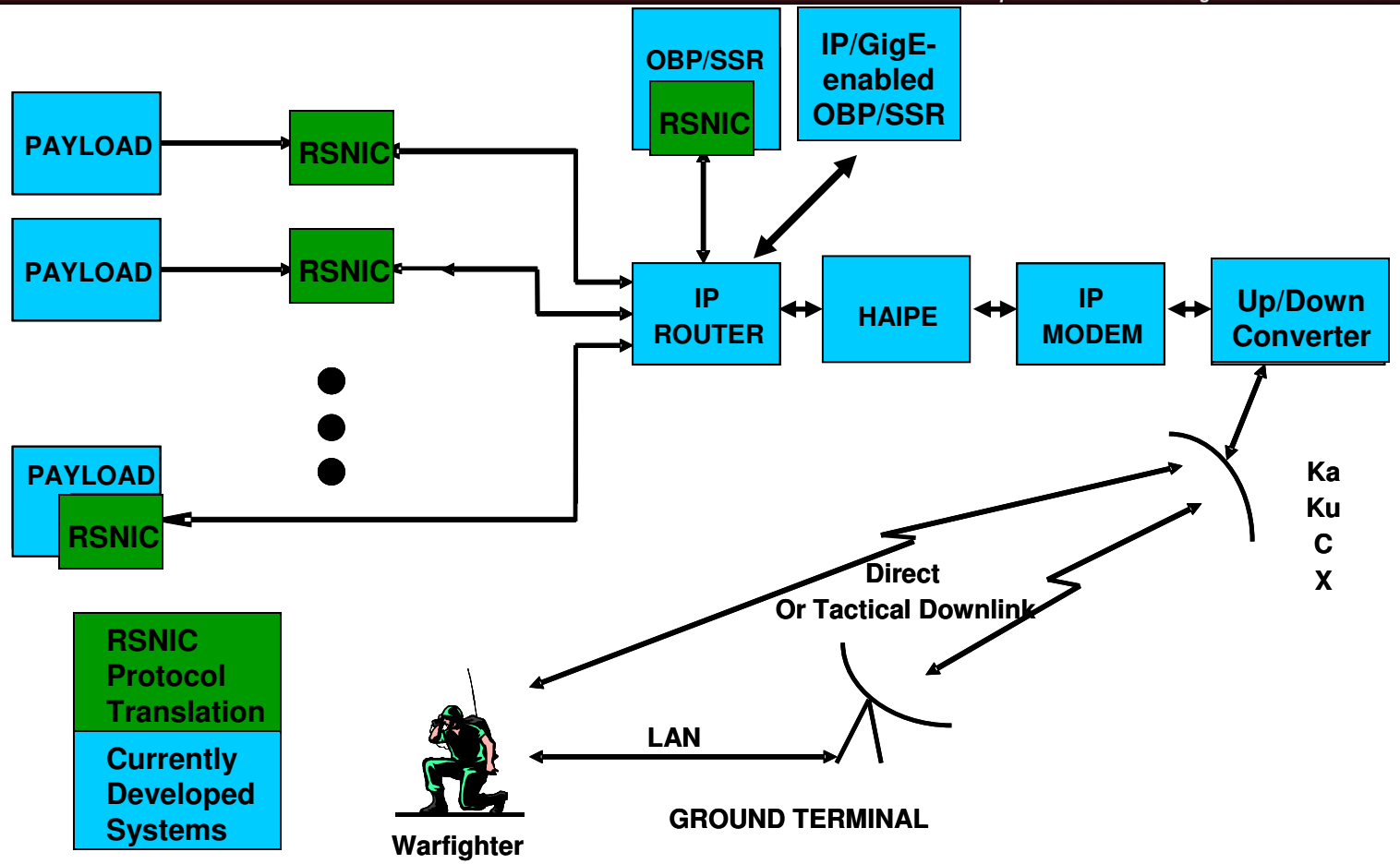
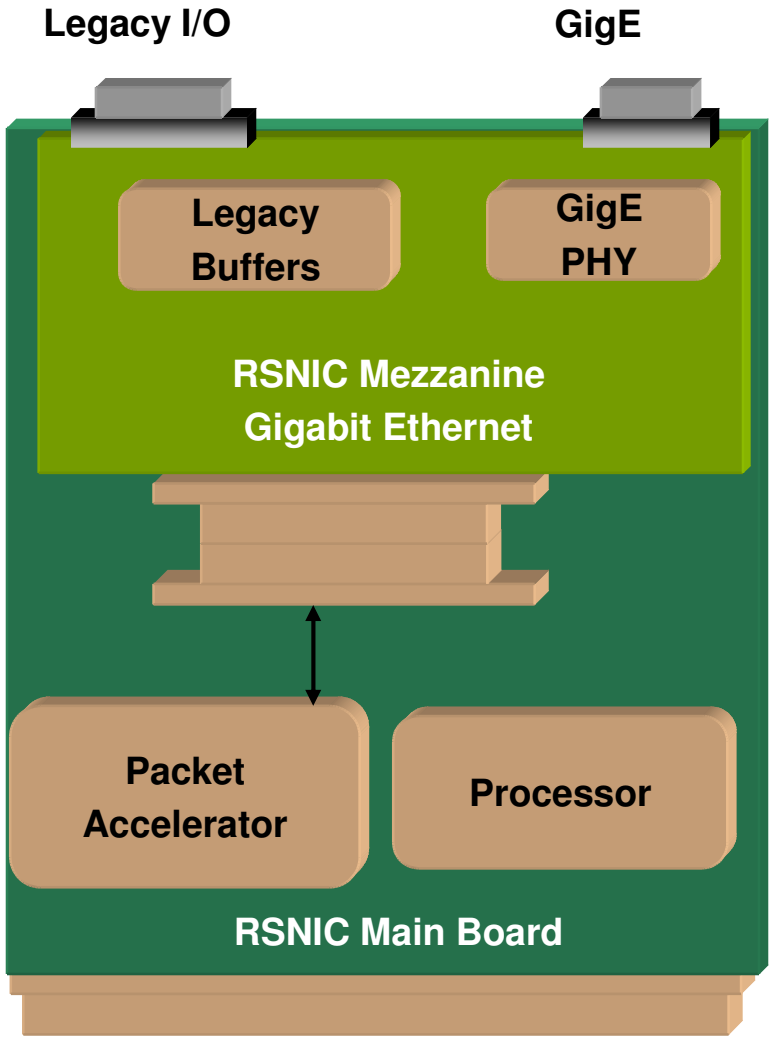


- RSNIC provides legacy protocol to IP/Ethernet translation to improve performance and scalability and enable plug-and-play payload design

RSNIC Interconnect Options

- RSNIC can be made to support a wide range of legacy I/O protocols
- LVDS/RS422 first interface developed
- Reconfigurability achieved by developing a new mezzanine card for each protocol with the RSNIC main board remaining the same
- RSNIC initially supports UDP over IPv4 over Gigabit Ethernet
- Support for other protocols under consideration in addition to Ethernet variations



RSNIC Design Overview

Personality Mezzanine Card

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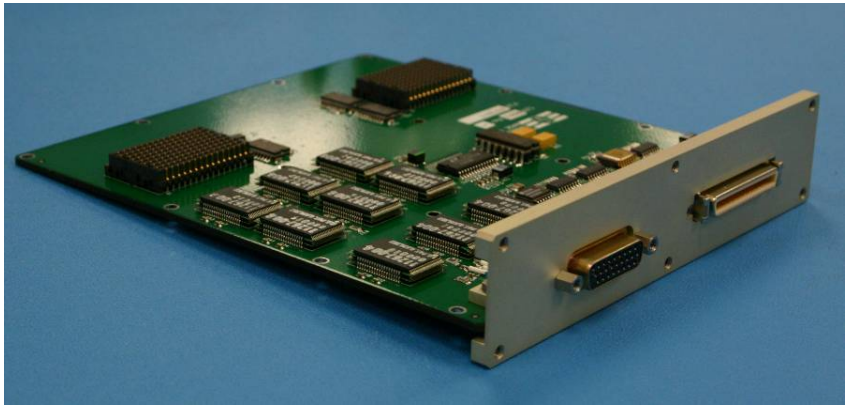
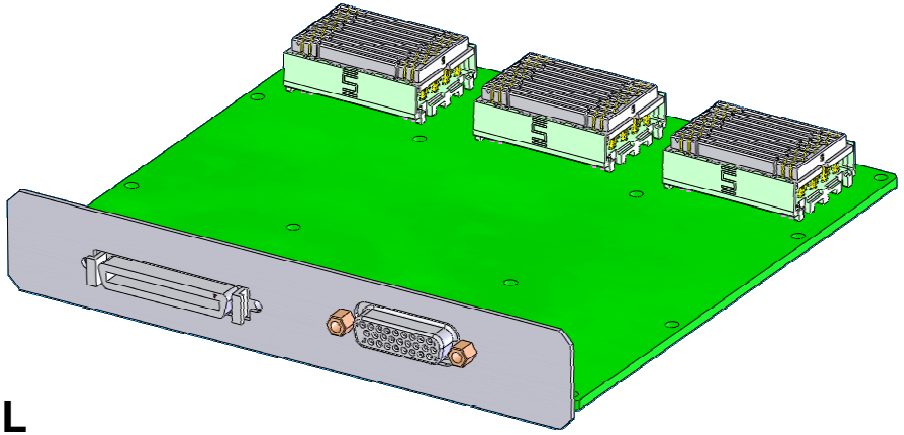
- Reconfigurability through mezzanine cards employed successfully on past projects
- AIP Personality Mezzanine for application specific functionality
  - Lower risk, quick development, lower costs
  - I/O and unique I/O connectors
  - Memory and Logic
  - TMR mitigation hardware
  - Analog circuitry ADC/DAC
- High speed mezzanine connectors
  - 170 high speed I/O
    - LVDS
    - High speed serial
    - TMR'd signals
- Technique successfully deployed on the responsive space Advanced Responsive Tactically Effective Military Imaging Spectrometer (ARTEMIS) mission on AFRL TacSat-3



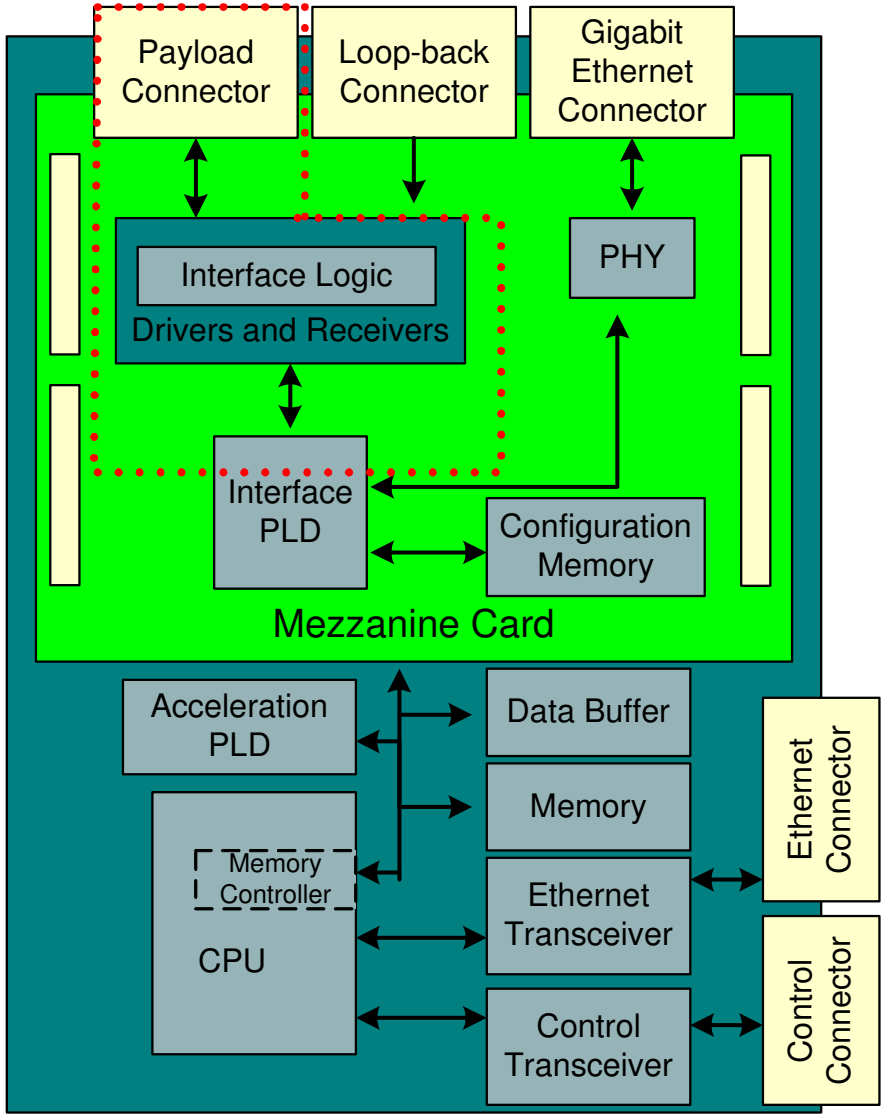
ARTEMIS Mezzanine



Three-connector Mezzanine Option

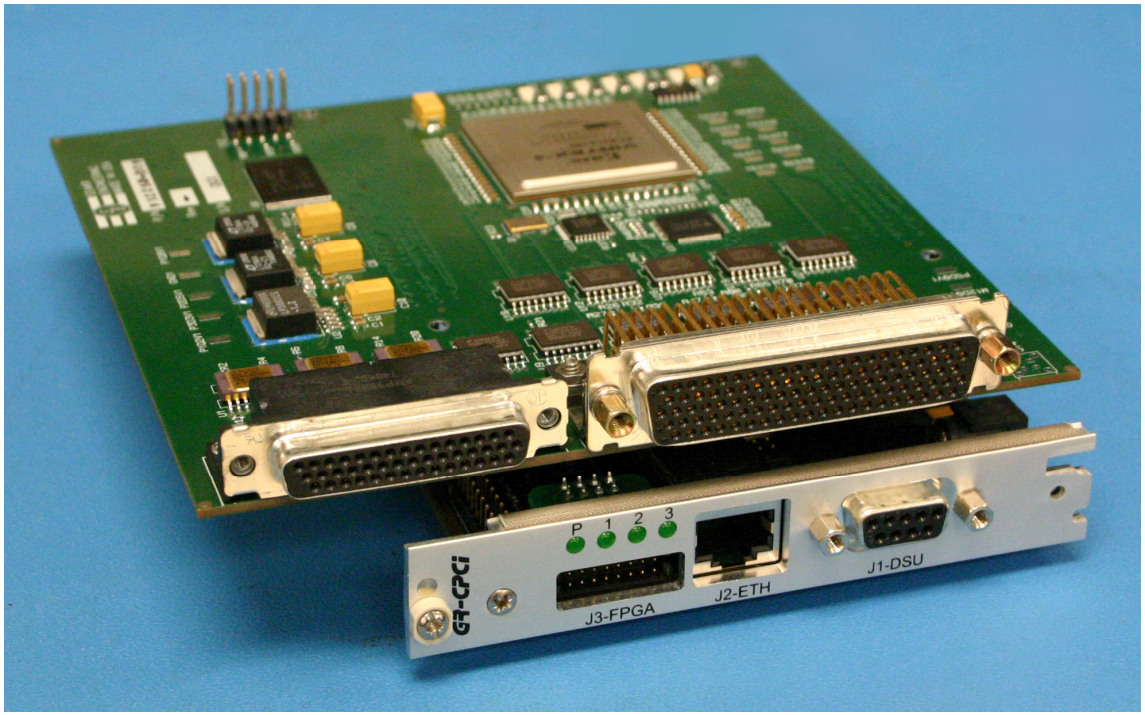
RSNIC Design

- **Merging of programmable logic devices for application and interface performance and sequential microprocessor for ease of development**
- **All functionality required for protocol translation encapsulated with the single board plus mezzanine card**
  - **PLDs provide interface acceleration**
  - **Memory for PLD configuration, processor instructions, computation and packet buffering**
  - **Options for either hardened or non-hardened PLD with mitigation**
  - **RSNIC device control provided via separate Ethernet or custom interface**
- **Mezzanine card designs largely stay unchanged with only the interface-specific portions requiring augmentation**



RSNIC Prototype Status

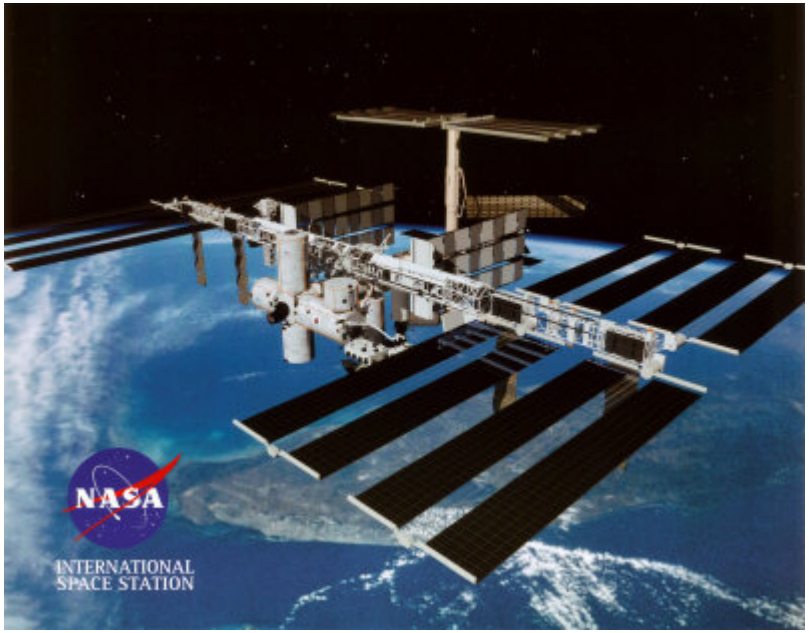
- RSNIC prototype boards developed and verified
- Ethernet and payload interfaces confirmed to be operational via loopback and PC generated traffic
  - Currently supports 300Mbps bandwidth measured using IP/UDP protocol transfers
- SSR Tech. Demonstration
  - Translate data and command traffic for the EM version of SEAKR's two-channel SSR used in NASA's Gamma-ray Large Area Space Telescope
  - Demonstration planned for September 2008



RSNIC Prototype

RSNIC Future Work

- **Expansion to include more interfaces currently under consideration**
  - **SpaceWire**
  - **IEEE1553**
- **RSNIC concept application in the International Space Station**
  - **Perform channel aggregation where previously not implemented to improve performance and system scalability**
  - **Additional use to perform protocol translation to Gigabit Ethernet**
- **Under consideration for future missions**



International Space Station

Conclusions

- Interconnection networks within spacecraft include mixture of disparate standards that are often custom versions for the aerospace industry
- Latest commercial technology can improve performance and scalability
- Unifying disparate protocols can improve interoperability while reducing non-recurring engineering
- SEAKR's Space Gigabit Ethernet and IP-centric payload provides capable core interconnection system
- RSNIC provides legacy protocol to IP/Ethernet translation to improve performance and scalability and enable plug-and-play payload design
- RSNIC prototypes developed and under test
- Demonstration using a SSR scheduled for September 2008
- Plan to develop additional mezzanine card options for other protocols

Acknowledgements

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References

1. Detlev Schaadt, “AFDX/ARINC 664 Concept, Design, Implementation and Beyond,” *SYSGO AG White Paper*, 2007.
2. L. Wood, et al., “Using Internet Nodes and Routers Onboard Satellites,” *International Journal of Satellite Communications and Networking*, **25**(2) , March/April 2007, pp. 195-216.
3. R. Schmidhuber, “International Space Station welcomes aboard ProCurve Networking,” *EADS Astrium Space Transportation White Paper*, January 2008.
4. J. Gal-Edd, “Evolution of the Lunar Network,” *Proc. IEEE Aerospace Conference*, Big Sky, MT, March 1-8, 2008.
5. F. Yegenoglu, et al., “TSAT Advanced Network Services and Routing Architecture,” *Proc. IEEE Aerospace Conference*, March 4-11, 2006.
6. Michel Bousquet, et al., “SATNEX, the European Satellite Communications Network of Excellence,” *Proc. International Workshop on the European Union Forum on Cooperative Scientific Research*, Prague, Czech Republic June 6-7, June 2005.

SEAKR Heritage

SEAKR Engineering, Inc.

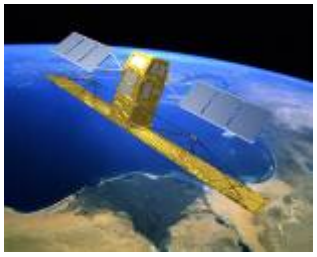
Aerospace Data Storage and Processing Systems

PRODUCT CODE
- Memory Systems
- On-Board Processors
- Manned Flight
- Spacecraft Avionics
- Satellite Communications
- Other-Than-Space

71 Launched Systems
100% Success Rate

Launched 1992 - 1996
- Clementine
- APEX
- MicroLabs
- RadarSat
- NEAR
- Spartan
- MGS
- ACTEX

Launched 1997 – 2000
- ACE
- SEASTAR
- MARS98
- P91
- QuickScat
- DMSP (F15)
- MightSat II



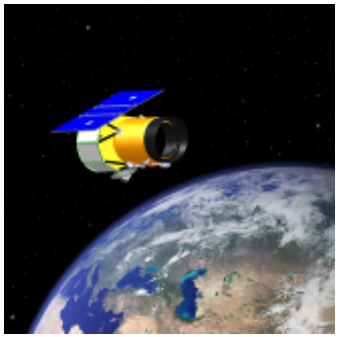
Launched 2001 - 2002
- Mars Odyssey
- GeoLITE
- Quickbird
- SAGE III
- HESSI
- MMU (Shuttle)
- HCOR (ISS)

Launched 2003 - 2005
- Coriolis
- ICE Sat
- GALEX
- Orbimage (3 & 4)
- DMSP (F16)
- Gravity Probe B
- MRO
- Swift

Launched 2005-2008
- Deep Impact
- CloudSat
- DMSP (F17)
- Cibola
- P909
- Phoenix Lander
- JEM HRDR
- JEM-SSEDSU
- Worldview-1
- Kepler
- Glast

Delivered
- ARTEMIS
- DMSP 5D3
- Challenger
- HDAS/DAAS
- LEO
- LTMPF
- MAU - C&DH
- MMSM
- NEMO
- NPP
- RCC-MAP
- SRB
- SSP
- DSX-ECS
- DSX-C&DH
- SBSS-SSR
- SBSS-C&DH
- WBDG
- Worldview-2
- PST
- SpaceCube
- WISE-FMC
- OCO

Development
- VPU
- NPOESS
- SBR-OBP
- IADMS - NGST
- SSP
- IRIS
- Digital Channelizer
- RSNIC
- C-17 MMC
- iAPS
- JWST SSR
- CEU



SEAKR's product mix shift from nearly 100% SSRs to 25 – 40% SSRs

Contact Information

SEAKR Engineering, Inc.

Aerospace Data Storage and Processing Systems

Dave Jungkind — **Business Development**
- **303-784-7734** — dave.jungkind@SEAKR.com

Matthew Fehringer — **RSNIC Program Manager**
- **303-708-5254** — matt.fehringer@SEAKR.com

Dr. Ian Troxel — **Future Systems Architect**
- **303-784-7673** — ian.troxel@SEAKR.com

SEAKR Engineering, Inc.
6221 South Racine Circle
Centennial, CO 80111-6427
main: 303 790 8499
fax: 303 790 8720
web: http://www.SEAKR.com