Commercial Sources for EDL Flight Tests

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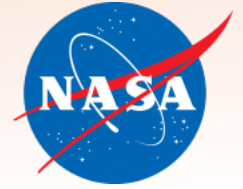
COTS

- What is COTS?
  - <u>C</u>ommercial <u>O</u>ff <u>T</u>he <u>S</u>helf
  - Is defined as a Federal Acquisition Regulation (FAR) term for commercial items, including services, available in the commercial marketplace that can be bought and used under government contract/s.
- A need for COTS exists to help in reducing avionics cost associated with applicable missions.
- In a 2014 a Planetary Science Decadal Survey it was stated that it is imperative that NASA expand its investment in fundamental technology areas
  - Reduced mass and power requirements for spacecraft and their subsystems
  - New and improved sensors, instruments, and sampling systems; and Mission and trajectory design and optimization
- Two goals were written as part of the technology investment:
  1. Reducing the cost of planetary missions
  2. Improving their scientific capability and reliability…."
- COTS could certainty aid in reducing cost associated with the instrumentation systems.

COTS in Space

- During the past several years there has been a movement towards a broader use of COTS equipment for use in space applications.

- Reasons:
  - Decreasing budgets associated with Science and Technology Demonstration Missions
  - Compressed mission durations

- NASA Directorates are now advocating on evaluating how COTS can be used for certain space applications and how we as an Agency can provide solutions to overcome some of their shortcomings.

Space COTS

- Space COTS is a relatively new term
  - The basis is standard Flight Test Instrumentation (FTI) COTS hardware
    - Use FTI COTS heritage and combined it with Space Qualification
      » Characterization, Mission Mapping, Adaptation, and Qualification
      - Reduce schedule risk while also decreasing costs
  - Designed using commercially available (non-space) components
    - However, several key product assurance components are implemented with the Space COTS Products as compared with standard FTI
    - Program specific product adaptation
    - Batch Controlled component procurement to maintain traceability/qualification
      » From Qualification to Flight Model
    - Qualification Testing
      » Thermal-Mechanical, EMI/EMC, Radiation, Thermal Vacuum
    - Functional and Environmental Acceptance Testing
    - Configuration Management Builds
    - Thermal and Mechanical Modeling
    - Certification/Documentation

Background on COTS in Space

- Launch Vehicles
  - COTS Data Acquisition Units have been used on Launch Vehicles for more than 10+ years
    - Delta II, III, IV
    - Shuttle SRB Load Monitoring
    - Space X – Falcon
    - Ares I-X
    - Atlas II, III, V
- Re-entry Experimental Vehicles
  - ESA IXV
  - Dragon
  - Orion/EFT-1
- ISS
  - Data Acquisition supports Advanced Closed Loop System (ACLS) for the COLUMBUS module

Key Commercial Vendors

- Key Data Acquisition Manufacturers

  - Curtiss-Wright/ACRA

    - ACRA, which is now part of the Curtiss-Wright Avionics & Electronics Group, is a multinational provider of highly engineered data acquisition products and services for Flight Test Instrumentation. The company has several decades of experience with Heritage on launch vehicles, X-planes, technology demonstrators, and re-entry vehicles

  - GOODRICH Data System (Now part of UTC Aerospace in Albuquerque, NM)

    - UTC Aerospace Systems is a major supplier of technologically-advanced aerospace and defense products.

      - They design, manufacture and service systems and components and provide integrated solutions for commercial, regional, business and military aircraft, helicopters and other platforms.

      - A major supplier to international space programs.

  - Teletronics Technology Corporation (TTC)

    - TTC is a major system solution provider for defense and commercial aerospace test applications.

      - Providers of a wide range of high-performance, reliable, modular, programmable, and miniaturized Commercial Off The Shelf (COTS) hardware and software products.

Curtiss-Wright/ACRA Background

6U Chassis

- Curtiss-Wright/ACRA Controls
  - Extensive experience with Flight Test Instrumentation
    - Most widely installed flight test instrumentation system in the World
  - They now have a dedicated Space Division
    - Approach
      - Adaptation of existing hardware design rather than re-design
      - Use of commercially available components
        » Leverage from COTS heritage, but with Space Qualification

3.88"

7.17"   3.15"
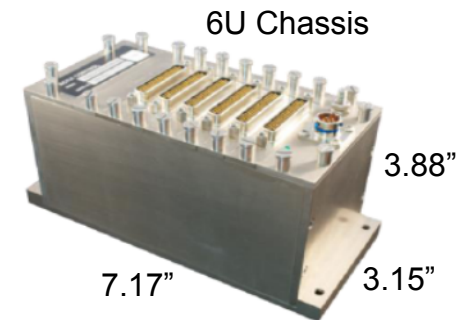
Curtiss-Wright/ACRA Features

- **Key Features:**
  - Products optimized for low cost of ownership
  - Modular system maps to multiple customer applications
    - Multiple Chassis
      - The chassis are manufactured in any integer multiple of card slots up to 13U.
    - Can support a wide range of sensor, actuator interfaces, and data buses
      - Over 100 modules to support almost any sensor
  - System Architecture:
    - Reliability is greatly driven by hardwired finite state machine
    - Systems are ruggedized and utilize conduction thermal principals
    - System balances size, mass & power with high performance & channel density
    - High System throughput
      - Up to 64Mbps (4Msps with 16 bits per sample) per chassis, aggregating up to gigabit per second throughput for a network distributed system

- **Environmental Testing:**
  - Thermo-Mechanical environmental testing: MIL-STD-810F for shock, vibration, temperature
    - 33grms (10-min per axis)
    - 16.5g each axis
  - EMC testing: MIL-STD-461E
  - Radiation Testing: 5000 Rad(Si) Total Ionizing Dose (Box Level) and 200 MeV Proton Irradiation (Board Level)
  - Thermal Vacuum Testing: from -40ºC to +85ºC at <1.0 x 10-5 mBar

CW/ACRA Product Overview

Data Acquisition Systems

- Highly rugged modular data acquisition units with an extensive range of COTS plug-in modules

FTI Recorders

- Stand-alone recorders with optional integrated data acquisition that exploits the KAM-500 library of modules

Rugged Switches

- Highly rugged, live at power-up IEEE 1588 PTP Ethernet switches

Ground Station Products

- Cutting edge bit sync and Smart Source Selector technology dramatically reduces frame drops

Software and Services

- Integrated setup, management and analysis software and services
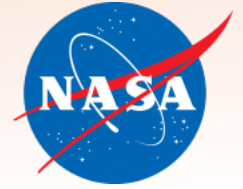
Radiation Assessment - ROM

- The "Total Absorbed Dose" for the cruise phase mission to Mars would be equivalent to about an 18 months stay on the ISS
  - This is well within the limits of radiation performance of the standard KAM-500 either powered on or off.
- The probability of a latch up radiation event at module level is estimated using the most complex ACRA module (KAD/BCU/140)
  - During proton irradiation tests calculated as 1.85×10^{-8} /cm^2
- Using published data on the proton flux at Mars and assuming fluxes between $1 \times 10^{+4}$ and $1 \times 10^{+5}$ protons/cm^2/sec
  - With this rate the estimated number of recoverable events during the 10 minute period could be as low as 0 and high as 10.
    - Leading to the loss up to10 cycles worth of data and <u>only from the affected module(s).</u>
- Surviving the unpowered cruise phase to Mars is extremely high for the KAM-500 with the SMART Backplane
  - The chances of failure once powered up and acquiring data at Mars is also extremely low.
  - Vender asserts that radiation events would be mitigated by the SMART Backplane, thus, minimizing data loss.

CW/ACRA Space Heritage

- Launch Vehicles
  - Delta II
  - Falcon 1
  - Falcon 9
- Re-entry Vehicles
  - Space Shuttle (STS 127)
  - Space Shuttle (STS 133)
  - Space X Dragon Demo, Re-supply missions
  - ESA IXV (Feb 2015)
- Sub-Orbital
  - Spaceship One
  - Spaceship Two
- On Contract to support Boeing CST-100
- Being evaluated to support second Orion Capsule Test Flight (EM) - 1

- **Key Points:**
  - A modular COTS system from Curtiss-Wright/ACRA Controls may be attractive for Discovery class missions
    - Dedicated Space Division
    - Multiple form factors are available
      - The chassis are manufactured in any integer multiple of card slots up to 13U.
    - The units are scalable and module which can reduce wiring mass and assist with mapping to customer specific applications
      - Over 100+ module available to support analog, digital, and data bus interfaces
    - Inherently resistant to radiation SEUs
    - New SMART Backplane can mitigate Single Event Latch Up
    - CCSDS Compatible Encoder (KAD/ENC/111)
    - Rad-Tolerant Remote Terminal Units (SEL resistant) being developed (available late 2017)

Cost Estimate for ESI

Hardware cost estimates on Engineering Science Investigation (ESI)

- **Total COTS DAS $930k:**
  - Engineering, Qual, and Flight Model Total: $220k
  - SE, Assurance, PM, etc.: $410k
  - Qual, Acceptance, NRE testing: $300k
- **KAM-500 Specs:**
  - 1U for TC: 15 channels
  - 2U for Strain gages: 16 channels
  - Controller and health monitoring modules
  - Draws ~16W (max) Power
  - Mass ~ 2168g (4.76lbs)
  - Data Interface with spacecraft computer via RS-422

- **Sensor Costs:**
  - 9 Flight Plugs + 6 spares: **$180k**
    - Assumes $12k per flight plug
  - Environmental testing for plugs: **$100k**
  - Arc jet testing for plugs: **$300k**
    - 5 days of testing w/ 10 instrumented models
  - 16 flight strain gages + 8 spare (includes pressure sensor: **$36k**
    - Assuming $1500 each (COTS ~$750)
  - Structural testing for gages: **$150k**
- **Labor costs for ESI:**
  - PI, PM, SE, engineering and design activities
- **Other items to cost:**
  - SLA-561S plug design
  - Wiring harnesses, connectors
- **Spacecraft Accommodations:**
  - Modifications for heatshield, backshell, and lander
  - Modifications to flight software
  - C-T scanner "time" for plugs
  - Integration time

GoodRICH/UTC Aerospace

- GOODRICH Data System (Now part of UTC Aerospace in Albuquerque, NM)

  – UTC Aerospace Systems is a major supplier of technologically-advanced aerospace and defense products.

    - They design, manufacture and service systems and components and provide integrated solutions for commercial, regional, business and military aircraft, helicopters and other platforms.

    - A major supplier to international space programs.

GoodRICH/UTC 9000 Series II DAS

- The 9000 Series II was the latest generation of Goodrich's Modular PCM Encoder System

- Specifically developed for high reliability, severe missile, and space environments

- Some of the technology advances offered by the 9000 Series II system are listed below:

  – Programmable formats, multi-format capability

  – Distributed system with master and multiple remotes

  – Integrated solid-state-recorders

  – Rugged design for very severe engine environments

  – Designed for radiation effects in space environments

  – High accuracy, 8, 10, and 12-bit resolution

  – Programmable bit rates up to 10Mbps

  – Integrated-programmable signal conditioning for all types of sensors

  – Programmable digital filtering

GoodRICH Parts - Radiation Environments

- All integrated circuits are MIL-PRF-38535 Class B/M/Q, MILSTD-883 Class B, or procured to a Class B SCD, are screened to MIL-STD-883

- All semiconductors are at least MIL-PRF-19500 JANTXV, or Class B SCD and are screened to MIL-PRF-19500 Appendix E. PIND, x-ray screens are performed to assure reliable operation in severe missile environments.

- Space Radiation Environments

  – The 9000 series has been the instrumentation system on many of the nation's launch vehicles that place satellites in orbit

  – They claim supporting hundreds of launch missions and accumulating thousands-of-hours of operation in orbital space without any failure and without any radiation-induced functional interrupts

GoodRICH Space Heritage

- Launch Vehicles
  - Delta
  - Sea Launch
  - Atlas V
  - Shuttle Upgrades
- Satellite Deployment
  - Combined Release and Radiation Effects Satellite (CRRES)
  - Cosmic Background Explorer (COBE)
  - Global Positioning Satellite (GPS)

- **Key Points:**
  - DAS built using project specific requirements
  - Parts traceability using , MILSTD-883 Class B, or procured to a Class B SCD, are screened to MIL-STD-883 components
  - They have designed for radiation environments of space
    - Supported hundreds of launch missions and accumulating thousands-of-hours of operation in orbital space without any failure and without any radiation-induced functional interrupts
  - Size and Cost may not be conducive to Discovery class missions
    - Further discussions with UTC Aerospace would be needed

Teletronics Technology Corporation (TTC)

- Teletronics Technology Corporation (TTC)
  - TTC is a major system solution provider for defense and commercial aerospace test applications.
  - Providers of a wide range of high-performance, reliable, modular, programmable, and miniaturized Commercial Off The Shelf (COTS) hardware and software products
  - Scalable systems that can be configured master/slave configurations
  - Adaptable as technology advances
  - Programmable through TTC Ware using RS-232
  - Support many different I/O configurations
    - Analog
    - Serial PCB
    - Ethernet,
    - RS-422/422
    - MIL STD 1553

TTC Form Factors - CDAU

- CDAU –XXXX
  - Fixed Volume (16U, 12U, 10U, 8U)
    - MIL STD-704 Power Supply
    - Mil "D" type connectors
    - Airborne internal connectors
    - Accepts RFI Mates & Back-shells
    - Built in Test Capability
    - Built in status
    - Integrated IRIG "B" time
    - Master slave capability
    - Wide band & Narrow band conditioning cards
    - Operating speed up to 20 MBPS

8U Chassis

5.4"

8.62"

4.97"

Plug-in Cards
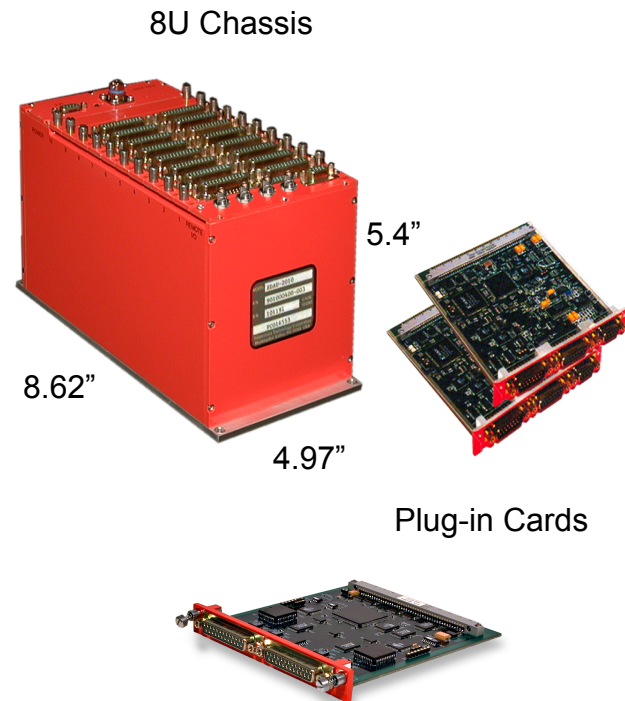
TTC Form Factors - MCDAU

- MCDAU- 2000 (Miniature DAS)
  - Modular & Expandable
    - Height is dependent upon number of modules
  - Micro D connectors
  - MIL STD-704 Pwr Supply
  - Airborne internal connectors
  - Accepts RFI Mates & Back-shells
  - Built in Test Capability
  - Built in status
  - IRIG "B" time capability
  - Master slave capability
  - Wide band & Narrow band conditioning cards
  - Operating speed of up to 20MBPS
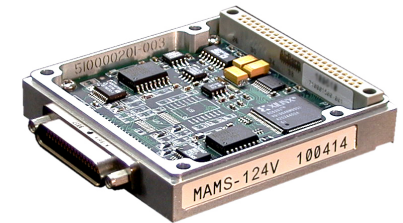
Module

Power Supply

2.4"   2.6"

Teletronics Space Heritage

- Heritage:
  - Launch Vehicles
    - Ares I-X
    - Delta
    - QRLV
  - Orbital Vehicles:
    - Orion Capsule Environmental Test Flight (EFT) - 1

- Key Points:
  - A modular and scalable system
    - Can reduce wiring mass and assist with mapping to customer specific applications
  - Both full size and miniature form factors available
    - CDAU (Full Size)
    - MCDAU (Miniature)
  - Plug-in cards and modules available to support just about any sensor, digital bus, and video needs
  - Not inherently resistant to radiation SEUs
    - Discovered during EFT-1 radiation testing
  - No Single Event Latch Up (SEL) Mitigation Hardware
    - EFT-1 chose to power down the units during certain portions of the orbital trajectory and entry where higher radiation environments were predicted
  - Not vested in developing space application products

Vendor Contact Information

- Curtiss-Wright ACRA Control

  – http://www.cwc-ae.com/acra-control

  – 665 North Baldwin Park Boulevard, City of Industry, CA 91746

  – Phone: (626) 851-3100

  – Fax: (626) 960-8500

- GoodRICH/UTC Aerospace

  – www.utcaerospacesystems.com

  – 6600 Gulton Ct NE, Albuquerque, NM 87109

  – (505) 345-9031

- Teletronics Technology Corporation

  – http://www.ttcdas.com

  – 15 Terry Drive, Newtown, PA 18940

  – Phone: (267) 352-2020

  – Fax: (267) 352-2021

Commercial Sources for EDL Flight Tests

BACKUP SLIDES

Backup Slides

CURTISS-WRIGHT/ACRA

Data Acquisition System Cont.

- The ACRA KAM-500 **is not** Rad hardened

  - However, their architecture has successfully been demonstrated in LEO

    - Their architecture includes a flash-based ProASIC3 FPGA that has some inherent radiation tolerance to SEU (bit errors) caused by particle radiation.

    - The module coefficients (filter settings, gain, offsets, etc.) are loaded from a ROM during each acquisition cycle thus refreshing the settings in the FPGA.

    - Nevertheless, standard commercial components are susceptible to Single Event Latch Up

- The CW/ACRA newly developed SMART backplane bridges gap between COTS and full custom system and provides additional radiation mitigation over their standard product

  - Detects single event upsets, resets daughter boards as needed

    - The SMART Backplane will power cycle any module that exhibits a latch up event with minimum loss of data (1 cycle per module event).

    - Constructed using rad-hardened components to protect the overall system

    - Triple redundancy on decision making paths

    - Orion Project tested Smart Backplane and showed that it was able to successfully protect itself along with the user modules from damage when exposed to Proton and Heavy Ion Tests.
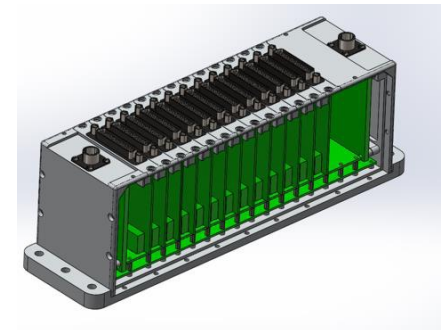
KAM-500 Analog Modules

Part #	Description
ADC/008	3 phase power monitor
ADC/010	Differential ended ADC (conditioning) - 2ch at 100ksps
ADC/111	Single ended ADC (conditioning) - 48ch at 4ksps
ADC/105	Differential ended ADC (conditioning) - 8ch at 24ksps
ADC/106	ICP accelerometer ADC (conditioning) – 6ch at 24ksps
ADC/109/S	Full-bridge ADC (excitation, conditioning) – 8ch at 24ksps
ADC/109/Q	Quarter-bridge 120/350Ω ADC (excit., cond.) – 8ch at 24ksps
ADC/112	Differential ended ADC (conditioning) - 24ch at 12ksps
ADC/113	PT100 quarter-bridge ADC (excitation, conditioning) - 16ch at 12ksps
ADC/114	Full or ½-bridge ADC (excitation, conditioning) - 16ch at 12ksps
ADC/116	ICP accelerometer ADC (conditioning, excitation) – 6ch at 24ksps
ADC/117	Full or ½-bridge ADC (excitation, conditioning) - 8ch at 24ksps
ADC/118	Full or ½-bridge, ADC (excit., bal., cond.) - 12ch at 12ksps
ADC/120	Full or ½-bridge, ADC (excitation, conditioning) - 12ch at 12ksps
ADC/126	ICP accelerometer ADC (wideband, conditioning) – 4ch at 100ksps
ADC/129	Full or ½-bridge, ADC (wideband, excit., cond.) - 4ch at 100ksps

Part #	Description
ADC/130	Differential ended ADC (high voltage, conditioning) - 4ch at 12ksps
ADC/132	Voltage ladder ADC (high voltage, conditioning) - 24ch at 12ksps
ADC/134	Full/1/2-bridge ADC (voltage excitation, strain gages, shunt resistor, 6.25kHz b/w) - 16ch at 25ksps
ADC/135	Full/½-bridge ADC (voltage/current excitation, programmable analog gain, 6.25kHz b/w) -12ch at 25ksps
ADC/136	Flexible ADC (full/½-bridge, ICP, PT100, thermocouple, FIR/IIR, 12.5kHz b/w) - 8ch at 50ksps
ADC/141	¼-bridge ADC (current excitation, PT100 temp. sensors, 6.25kHz b/w) - 16ch at 25ksps
CDC/002	Current to digital converter
CDC/101	Charge-to-digital converter for piezoelectric devices
LDC/101	LVDT/ RVDT ADC (conditioning, excitation) 4ch at 24ksps
MDC/001	External multiplexing A/D converter
MDC/002	Multiplexing ADC, with external TC
MDC/103	Multiplexing ADC, with polynomial TC
SDC/101	Synchro-to-digital convertor – 2ch at 24ksps
TDC/102	Thermocouple ADC with reference compensation – 15ch
TDC/107	Thermocouple ADC (conditioning, cold junction) - 12ch at 8sps

KAM-500 Bus Modules

Part#	Description
KAD/ABM/101	ARINC 429 bus monitor snarfer/parser - 8ch
KAD/ABM/102	ARINC 429 bus monitor parser/packetizer - 8ch
KAD/ABM/103	ARINC-429 bus monitor parser/packetizer - 24ch
KAD/ARI/002	ARINC 429 transmitter - 1ch
KAD/ARI/103	ARINC 573 bus monitor parser - 1ch
KAD/ARR/101	AFDX redundancy remover - 1ch
KAD/CBM/101	CCDL bus monitor parser - 4ch
KAD/CBM/102	CAN bus monitor parser - 4ch
KAD/CBM/103	CCDL/MCDL bus monitor parser - 4ch
KAD/CBM/104	CSDB bus monitor parser - 4ch
KAD/CBM/105	CAN bus monitor packetizer - 4ch
KAD/CBM/107	CAN bus monitor parser/packetizer - 4ch
KAD/EBM/101	Ethernet bus monitor parser - 1ch
KAD/EBM/102	Gigabit Ethernet bus monitor parser - 1ch
KAD/EBM/103	ARINC 429 on AFDX bus monitor parser -1ch
KAD/FBM/102	Firewire bus monitor parser - 1ch
KAD/FBM/103	Firewire S200b bus monitor parser - 1ch

Part#	Description
KAD/FBM/105	Firewire S400b bus monitor parser (and passthrough port) - 1ch
KAD/HBM/102	G1000 HSDB bus monitor parser - 1ch
KAD/MBI/001	MIL-STD-1553 remote terminal - 1ch
KAD/MBM/101	Dual redundant MIL-STD-1553 bus monitor with PARSER-packetizer – 3ch
KAD/MBM/102	MIL-STD-1553 bus monitor parser/packetizer - 4ch dual redundant
KAD/MSB/103	MIL-STD-1553 bus monitor parser - 1ch dual redundant
KAD/PBM/001	Panavia bus monitor parser - 8ch
KAD/PBM/002	MC/ENMC bus monitor snarfer/parser - 1ch
KAM/SBM/101	EFAbus Express/STANAG 3910 bus monitor parser - 1ch dual redundant
KAD/SDI/103	Serial data bus monitor parser - 1ch
KAD/TBM/101	TTP bus monitor parser/packetizer - 1ch dual redundant
KAD/UAR/102	RS-232/422/485 bus monitor snarfer/parser - 4ch
KAD/UAT/101	RS-232/422 asynchronous transmitter - 8ch
KAD/UBM/101	RS-422/485 serial bus packetizer - 8ch
KAD/UBM/103	RS-422/485 serial bus parser/packetizer - 16ch
KAD/UBM/104	ABI/ACE-CCDL/ACB serial bus monitor parser/packetizer - 8ch

- **Parser** - Extracts specific data from a bus and places it into defined words along with status information.
- **Snarfer** – Extracts all traffic and tags, along with content identifiers. Sometimes referred to as All-bus monitoring.
- **Packetizer** – All messages/ transactions on a bus are captured and time tagged, and encapsulated in the payload of a packet. This reduces the amount of bandwidth and storage space needed as stale data is not constantly being pushed through the system.

Other Available Modules

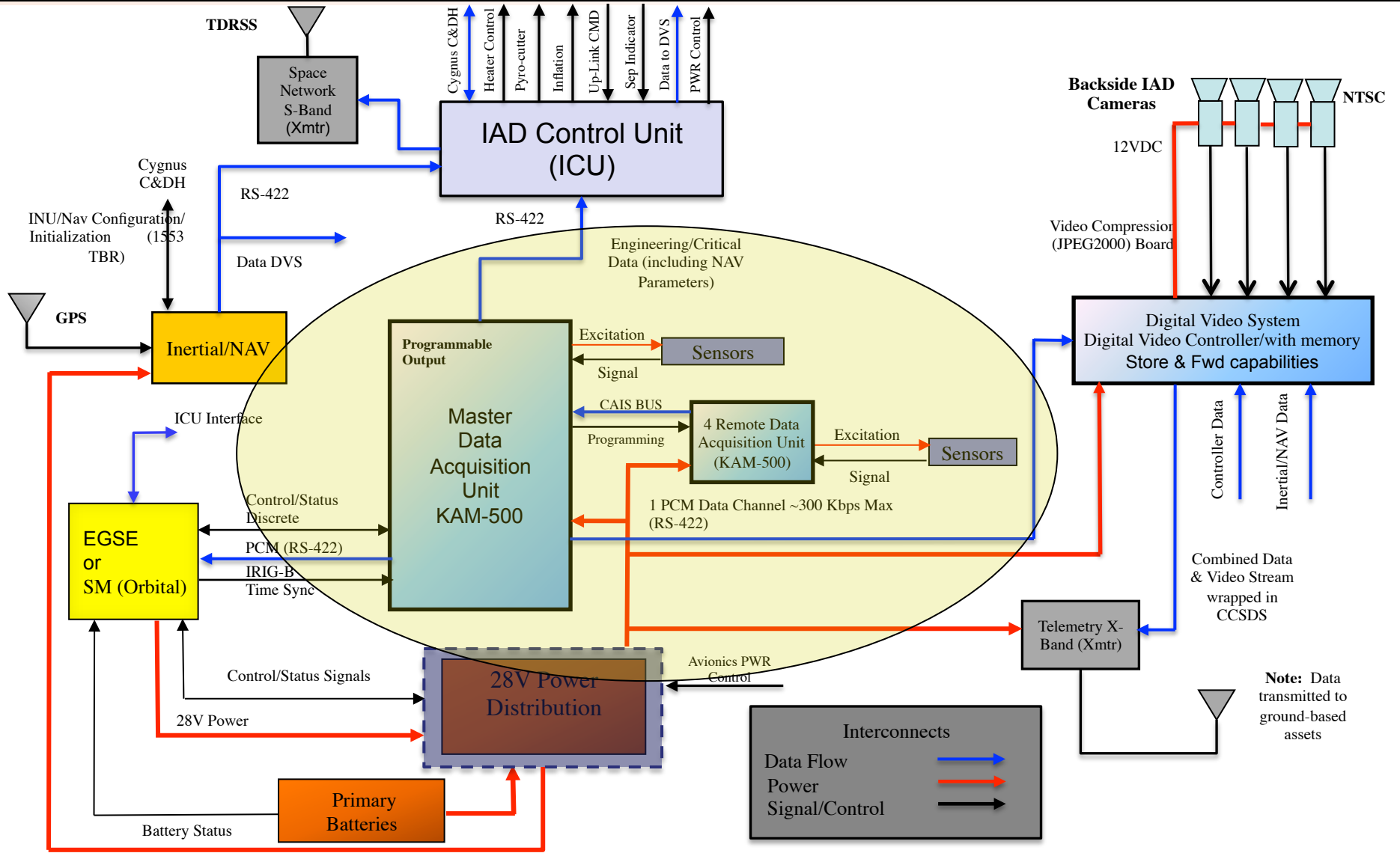| Part#	Description
Backplane Controller	
KAD/BCU/101	IRIG-106 backplane controller and encoder
KAD/BCU/140	Ethernet backplane controller - iNET-X compatible
KAD/BCU/142	Ethernet backplane controller - IENA/iNET-X compatible, PTPv1 client and Grandmaster, PTPv2 Client
KAD/MBC/001	MIL-STD-1553 bus controller
Digital	
KAD/DPI/002	Data input (RAM reader) - dual-port
KAD/DSI/102	Discrete input (counters, time tagging) - 24ch
KAD/DSI/104	Bi-level optically isolated input (counters, time tagging) - 24ch
KAD/SDI/001	Serial data input (clock out) - 8ch
Ethernet	
KAD/ETH/101	DA and programming over Ethernet – 3ch
KAD/ETH/102	iNET-X, 2.5Msample/sec, DA and programming via Ethernet – 3ch
KAD/SWI/101	3 to 1 aggregator Ethernet switch
KAD/SWI/102	2 to 2 aggregator with console port
KAD/SWI/107	Ethernet tap module 4-port
KAD/SWI/108	Ethernet switch (Xbar) - 4 port

Part#	Description
Miscellaneous	
KAD/BIT/101	Built-in self test – 14ch
KAD/BIT/102	Built-in self test for networked FTI – 14ch
KAD/DAC/001	Analog and discrete outputs – 24ch
KAD/ENC/106	IRIG-106 PCM encoder with PMF output - 14ch
KAD/ENC/111	CCSDS encoder with Ethernet interface and internal 64MB memory buffer
KAD/MAT/101	User-programmable microcontroller with embedded DSP
KAD/MEM/004	CompactFlash, data extraction via Ethernet
KAM/MEM/103	CompactFlash memory
KAD/RTC/002	Real-time clock (RTC) generator
KAD/RTC/003	RTC generator with memory status outputs – 2ch
KAM/TCG/102	Combined GPS and IRIG input -14ch
KAD/UTL/102	Format select line sequencing – 5ch
KAD/VDC/001	CVSD voice to digital converter – 2ch
KAD/VID/103	MPEG-4 video encoder (analog video input) - 1ch
KAD/VID/106	H.264 video encoder – 1ch

Non-Networked (PCM Based) Architecture

TDRSS

Space Network S-Band (Xmtr)

Cygnus C&DH | Heater Control | Pyro-cutter | Inflation | Up-Link CMD | Sep Indicator | Data to DVS | PWR Control

IAD Control Unit (ICU)

Backside IAD Cameras — NTSC

12VDC

Cygnus C&DH

RS-422

INU/Nav Configuration/ Initialization (1553 TBR)

Data DVS

RS-422

Engineering/Critical Data (including NAV Parameters)

Video Compression (JPEG2000) Board

GPS

Inertial/NAV

Programmable Output

Excitation

Signal

Sensors

Digital Video System Digital Video Controller/with memory Store & Fwd capabilities

ICU Interface

Master Data Acquisition Unit KAM-500

CAIS BUS

Programming

4 Remote Data Acquisition Unit (KAM-500)

Excitation

Signal

Sensors

EGSE or SM (Orbital)

Control/Status Discrete

PCM (RS-422)

IRIG-B Time Sync

1 PCM Data Channel ~300 Kbps Max (RS-422)

Controller Data

Inertial/NAV Data

Control/Status Signals

28V Power

28V Power Distribution

Avionics PWR Control

Combined Data & Video Stream wrapped in CCSDS

Telemetry X-Band (Xmtr)

Primary Batteries

Battery Status

Note: Data transmitted to ground-based assets

Interconnects
Data Flow →
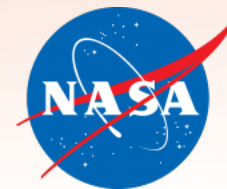Power →
Signal/Control →

Backup Slides

GOODRICH/UTC AEROSPACE

GoodRICH 9000 Series II Modules

Space Flight Systems
Albuquerque New Mexico
505 345 9031

9000 Module Summary

Model Number	Description/Title	Channel Count
9000-500	Input Filter Power Supply	-
9000-501	Main Power Supply	-
9000-502	5/10Vdc Excitation	-
9000-503	28Vdc Excitation	-
9000-511	Single-Ended High Level Group	64
9000-512	Double-Ended High Level Group	32
9000-513	Double-Ended Low Level Group	32
9000-514	RTD Group	32
9000-516	High Frequency Double Ended Group	8
9000-519	Strain Gage Group w/Integrated Excitation	24
9000-520	Control Logic/Format Data Group	
9000-521	Pulse Counter Group	4
9000-522	Bilevel Group	96
9000-523	1553 Remote Terminal Group	1
9000-524	Master Transmit Bus Interface	3
9000-525	Master Receive Bus Interface Group	3
9000-526	Serial Digital Interface Group	8
9000-527	Remote Bus Interface	-
9000-528	Digital Filter/Intelligent Processor Group	-
9000-529	Solid State Recorder Group	-
9000-531	Charge Converter Module	1

Backup Slides

TELETRONICS TECHNOLOGY CORPORATION

Distributed TTC DAS Architecture

Ground Stations

Ground Stations

Antenna

Antenna

First Stage

Transmitter

Transmitter

Solid State Recorder

Launch Abort System & Crew Module

Sensor Data

0.5 Mbps

5.5 Mbps

11.2 Mbps

Service Module & Space Craft Adaptor

Sensor Data

0.5 Mbps

4.7 Mbps

Sensor Data

5.5 Mbps

Data Combiner MARM-2000

Data Combiner MARM-2000

1 Mbps!

4.5 Mbps

Upper Stage

Sensor Data

Antenna

Antenna

Sensor Data

Solid State Recorder

Ecliptic RocketCam²

Ecliptic RocketCam²

Minotaur AVS

Minotaur AVS