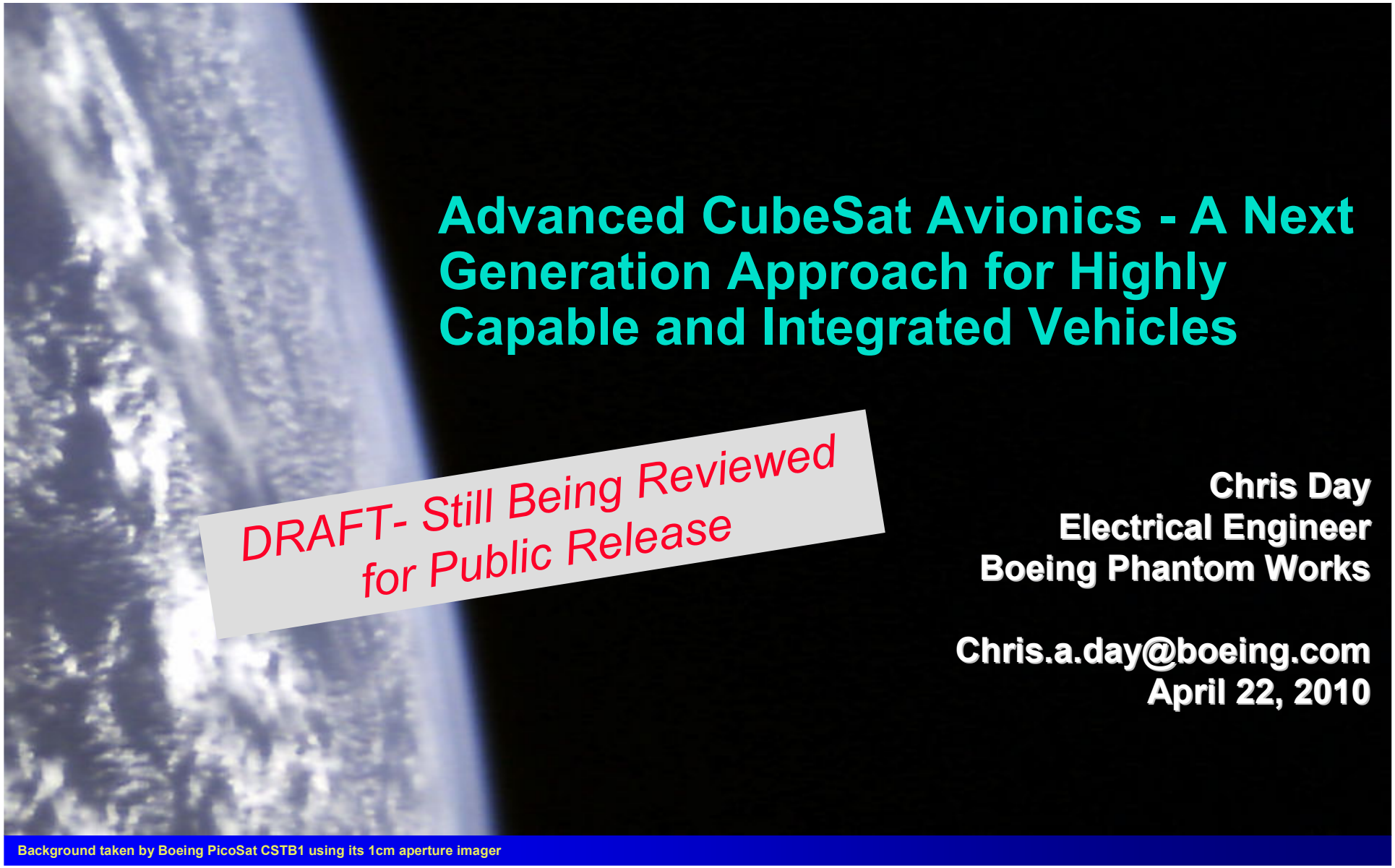
BOEING

PHANTOM WORKS



Advanced CubeSat Avionics - A Next Generation Approach for Highly Capable and Integrated Vehicles

DRAFT- Still Being Reviewed for Public Release

Chris Day
Electrical Engineer
Boeing Phantom Works

Chris.a.day@boeing.com

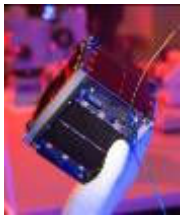
April 22, 2010

Background taken by Boeing PicoSat CSTB1 using its 1cm aperture imager

Current Market Trends

- **Transition from space experiments to operational missions**
  - Need for increasing reliability / redundancy / flexibility
- **Increasing vehicle performance and utility**
  - Precision pointing with use of reaction wheel assemblies, miniature star cameras and IMUs
  - Higher power system which use deployable arrays Need for increased onboard processing to support advanced flight controls and payload processing
  - Propulsion for orbit maneuvering or maintenance
- **Multi-objective missions**
  - Multiple payloads or operating modes

Past/Present



Payload
C&DH
EPS
Comm

Performance

Payload 1	Payload N
C&DH	Propulsion
EPS	Star Camera
Comm	IMU
Solar Panels	RWA

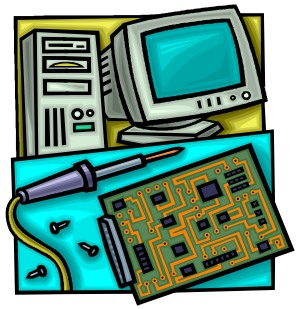
Future

SYSTEMS BECOMING INCREASINGLY COMPLEX

Existing Vehicle Design Approaches

- **Plug and Play Approach**
  - Example: AFRL Space PnP Avionics (SPA) technology
  - Allows rapid integration of previously designed modules and subsystems
  - Payload and advanced subsystems must conform to rigid physical, electrical and software standards
  - Overhead required for interfacing to simple payloads

- **Computer Bus Approach**
  - Example: PC-104 form factor
  - Allows a very standardized form factor
  - Limits connector location and pin allocation & qty

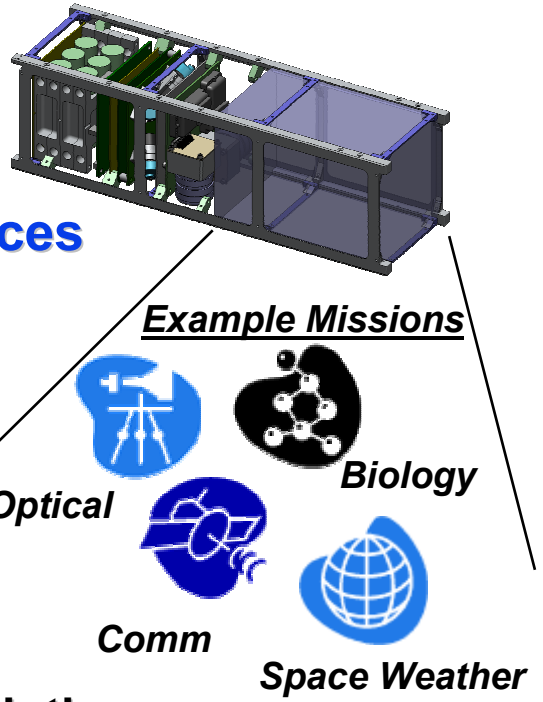


- **Custom Approach**
  - Examples: Majority of CubeSat developers
  - Customized bus for payload needs
  - Requires excessive time and money to make each custom satellite

NO EXPANDABLE SOLUTION OR STANDARD EXISTS TODAY

Payload & Component Interface Design Challenges

- **Payload types and interfaces vary widely from the extremely simple to complex**
  - Measurement of simple voltage readings
  - Enable line with data streaming over serial
  - Full duplex serial communications
- **Desire is to minimize number and types of interfaces**
  - Accommodate high power devices
  - Provide standard voltages
  - Analog to digital measurements
  - Number of digital I/O for enable and interrupts
  - Serial communications
- **Finding the right balance of interface designs**
  - Standard interface – one size does <u>not</u> usually fit all
  - Custom interfaces – <u>cost prohibitive</u> to redesign each time
- **NEED EXISTS FOR A SIMPLE, FLEXIBLE INTERFACE FOR MANY PAYLOAD TYPES**



Based on these Design Challenges, We have developed a Initial solution

Flexible CubeSat Payload & Component Electrical Interfaces: "CS82"

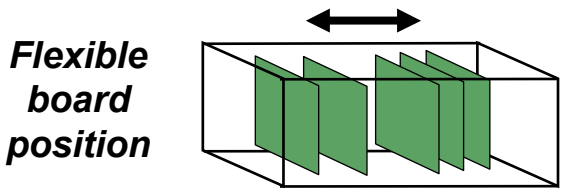
- Standard Interfaces Address Wide Range of Missions

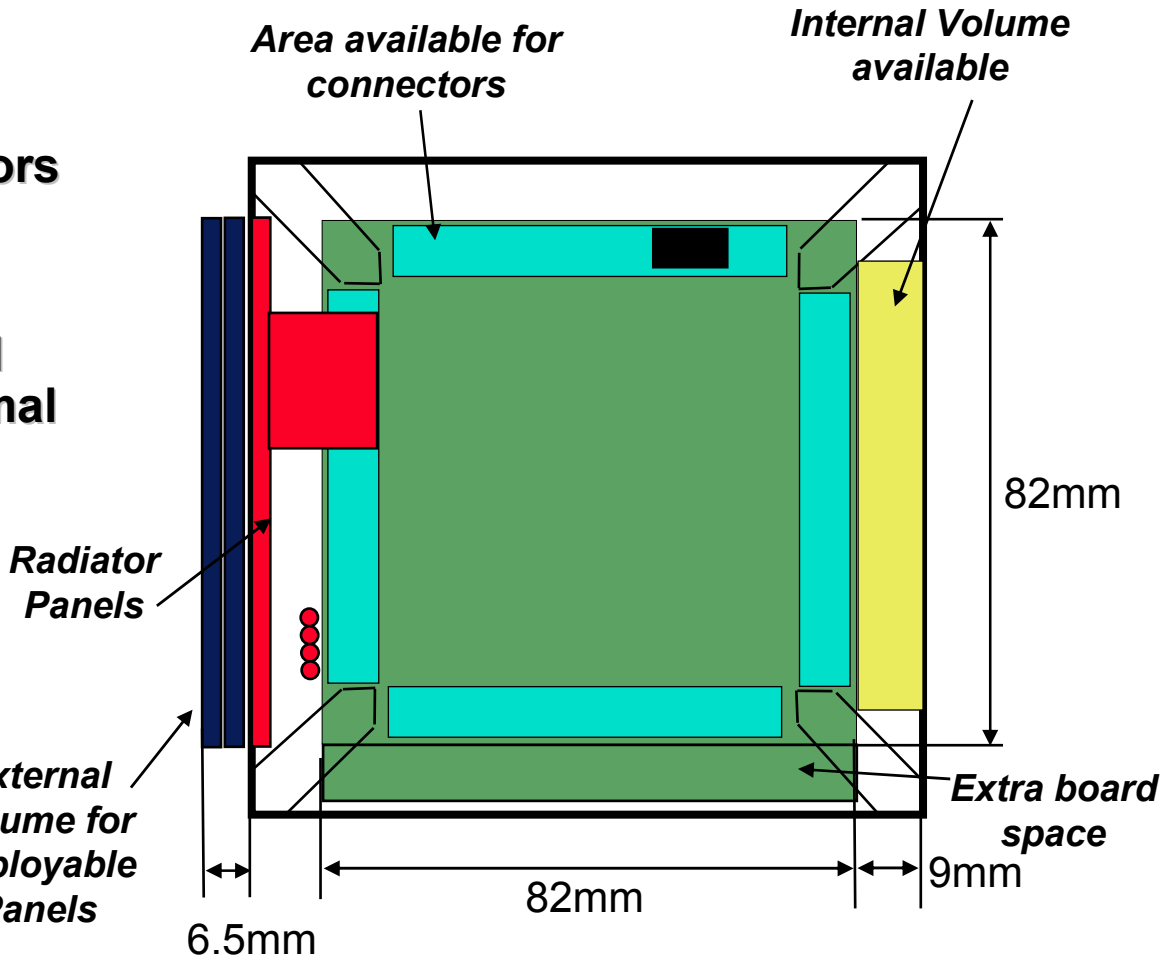
Power Supply	Voltage	Max. Current	Description
Regulated 3.3V, 0.5A	3.3V	0.5A	Used for low power and low voltage circuits
Regulated 1.2V to 9V, 2A	1.2V to 9V	2A	Voltage based on payload needs
Unregulated 9-12.6V, 7A	9V to 12.6V	7A	High power payloads can use this high current power supply

Data Communication	Nominal Range	Description
Analog Channels: 3 Resolution: 12 bit	0V to 2.048V	Useful for temperature measurements and basic status analog values. Some payloads (e.g. sun sensors) only need power and supply an analog output.
Digital I/O Number: Up to 6 I/O	0V to 3.3V	Used for activating payloads and basic communication and handshaking between payload and bus.
Serial RS-422	0 to 1 Mbps	For most payloads, an RS-422 connection provides a convenient data channel from a payload uP UART to the satellite bus
Pulse per second (PPS signal)	0V to 3.3V	Used for time synchronization between satellite bus and payload

Flexible CubeSat Payload & Component Mechanical Interface

- **Advantages of compact board form factor**
  - Flexible areas for connectors
  - Cabling/harness can be routed along side
  - Internal area for side panel components such as thermal radiator panels
  - Fully compatible with the open Tensor™ CS class frame structure





HIGHLY ADAPTABLE INTERNAL VOLUME ALLOWS MANY LAYOUT CONFIGURATIONS

Conclusions

- Complexity of CubeSat systems increasing to support growing mission needs
- Existing Standards are limited in ability to support the high performance needs of CubeSats
- A key design challenge is designing a simple, yet flexible interface that can accommodate many subsystem and payload types
- Boeing experience and mission insights has driven us to develop a new flexible and extensible set of electrical and mechanical interfaces

Would like to explore with other interested organizations creating a forum for continued evolution of "CS82"

Thank You