CINEMA CubeSat Flight Software

Handling High Data Rates

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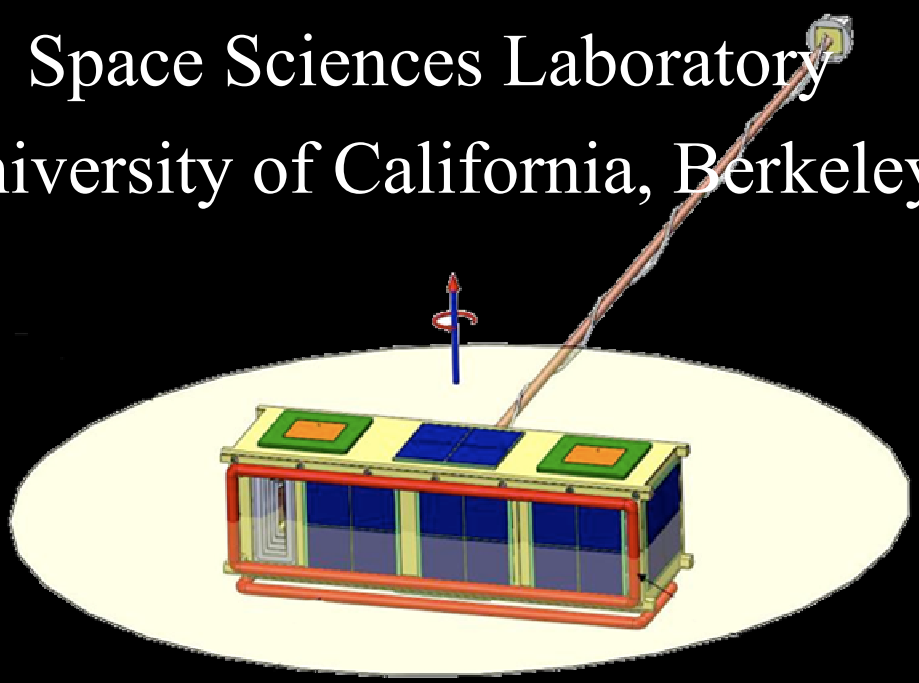


CubeSat Developer's Workshop April 21, 2010

CINEMA has been brought to you by:

Principal Investigator
Robert Lin, SSL

System Engineer
David Curtis, SSL

STEIN Scientist
Davin Larson, UCB

MAGIC Scientist
Tim Horbury, ICL

Other contributors:
David Glaser, SSL
Dorothy Gordon, SSL
Peter Harvey, SSL
John Sample, SSL

CINEMA

(CubeSat for Ions, Neutrals, Electrons and MAgnetic fields)

- Monitor space weather
- Demonstrate self-orientation, miniaturized sensors, CubeSat possibilities
- Main sensors: STEIN particle detector, magnetometers

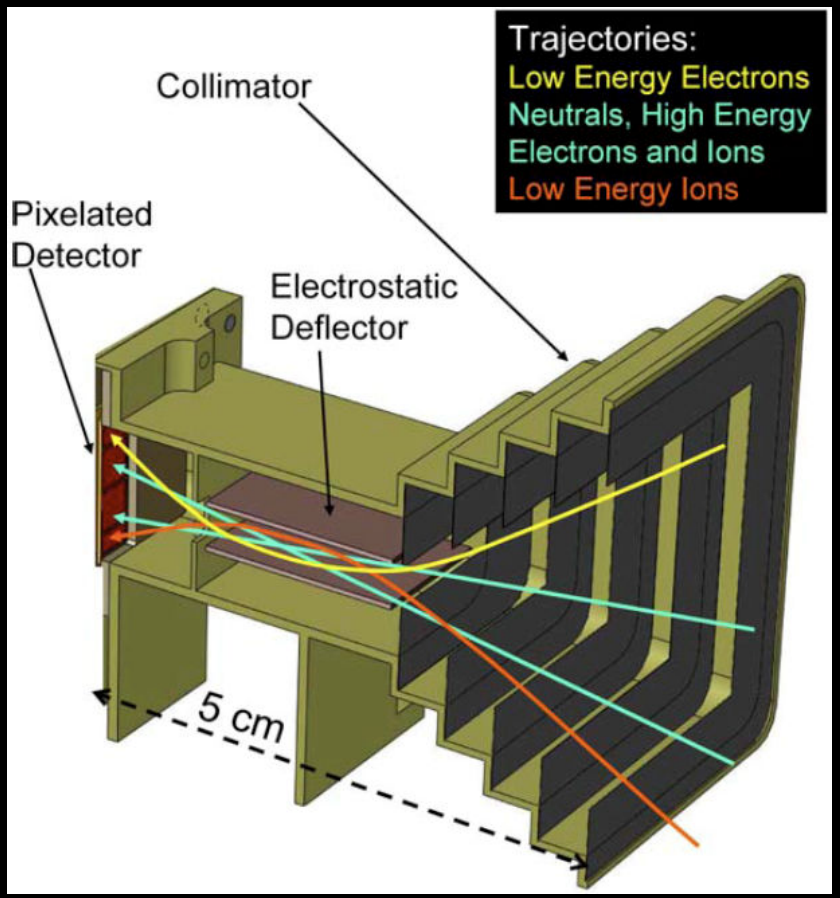
STEIN Particle Detector

STEIN: SupraThermal Electron, Ion, Neutral

Four detector “pixels”, ≤30K counts/sec each

Range: few to 100 KeV

Resolution:
~1 KeV FWHM

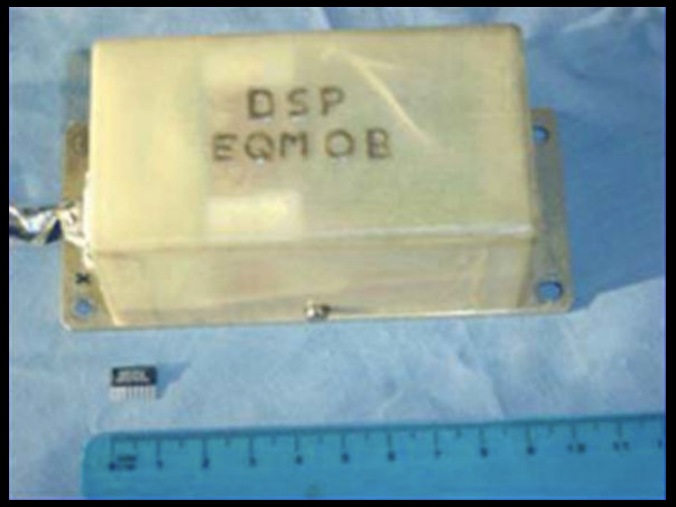


Magnetometers

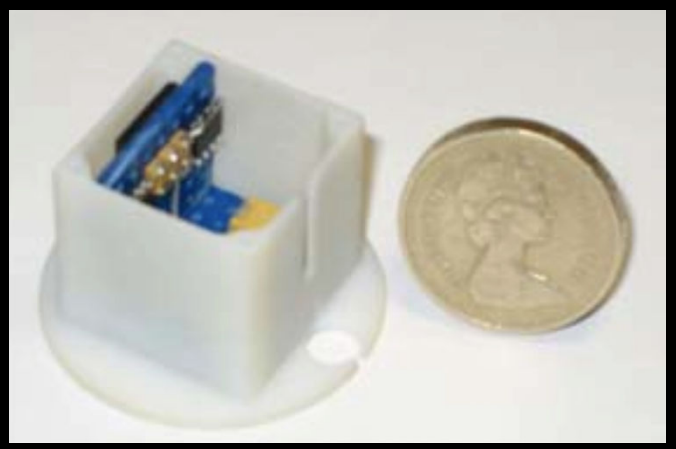
- Magnetoresistive magnetometers minimize size
- 3 axes, inboard and boom-deployed
- Resolution: 2-10 nT in science mode, 25 nT in ACS mode

Fluxgate mag.

MR mag. (1-axis)



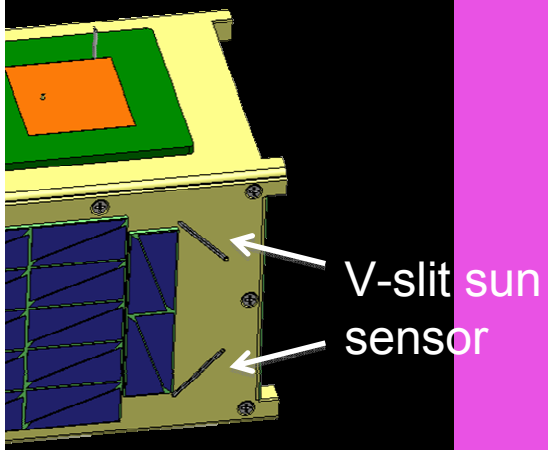
MR mag. assembly (3-axis)

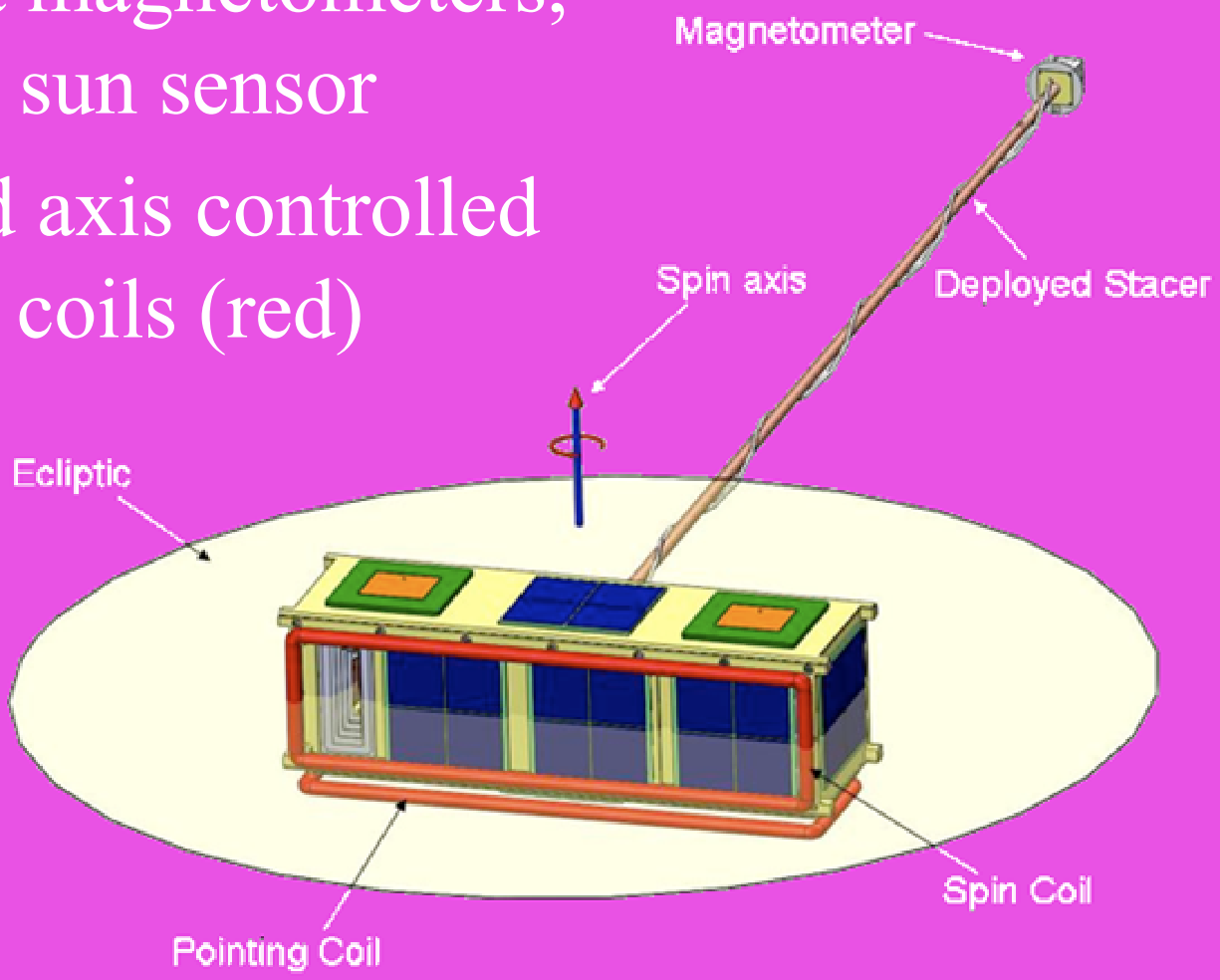


Attitude Control System (ACS)

Axis found via magnetometers, solar panels, sun sensor

Spin speed and axis controlled using torque coils (red)





Solid State Storage

- Standard SD card
- Shock and vibration tested
- Resistant to temperature extremes (-25°C - 85°C)
- Holds well over a week's worth of data (average)

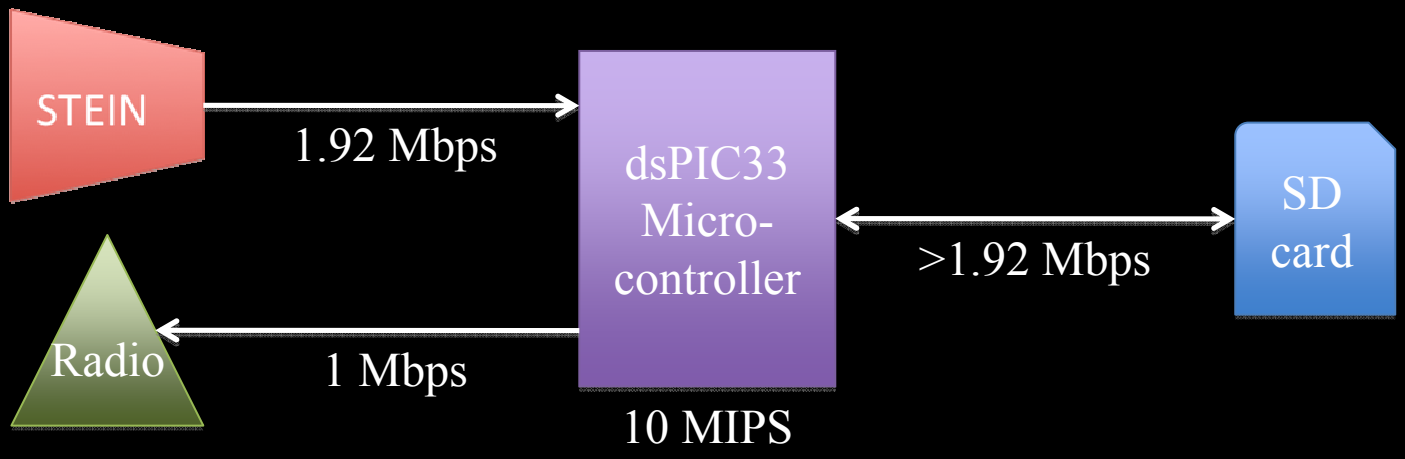
System Modes

- Safe – Minimal Power Configuration, all optional systems off; boots/resets to Safe
- ACS – Only SD card, torque coils, and low speed MAG active; used to control attitude
- Science – SD card, STEIN, and MAG active, radio transmit allowed, torque coils disabled
- Engineering – Everything enabled

Mission Plan

- Early operations
  - Safe Mode until contact with ground station
  - Deploy magnetometer boom
  - Self-diagnostics, calibration
  - Reorient spin plane to ecliptic, spin up
- Normal operations
  - STEIN, mag. collecting data at full speed
  - Ground contact at least once/day

Maximum Data Rates



- STEIN: 120K particles/sec peak, 16 bits/particle
- All data stored on SD card; must handle peaks
- RF downlink: 1 Mbps constant
- 10 MIPS processor limit (power consumption)

Dealing with Demands

- Using max-size blocks & interleaving reading/writing requires almost $^1/_2$ of processor (peak)
- Doesn't include SD card busy time fluctuations
- Ability of RTOS to regularly schedule this task plus many others unknown, also overhead
- More deterministic solution desired

Task Division

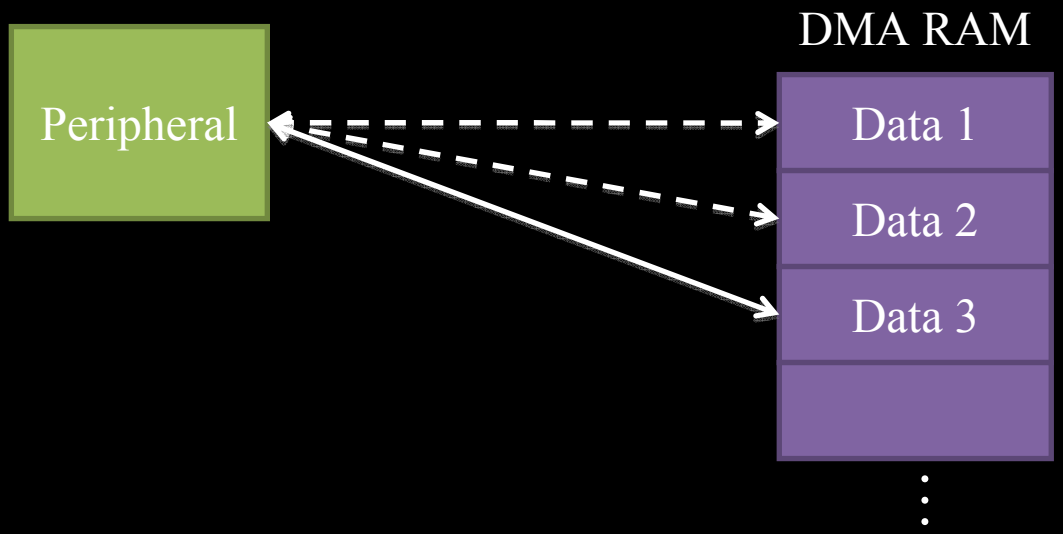
- Background tasks
  - Run at specific times
  - Must finish within a fixed time limit
  - Command handling, ADC sampling, data transmission…
- Foreground tasks
  - Run asynchronously, round-robin in remaining time
  - No hard limit on execution time
  - ACS calculations, SRAM scan, memory peek/poke…

Background Task Scheduling

- Each task must run with a given frequency
- Fixed schedule ensures this
- Tasks must finish in allotted time

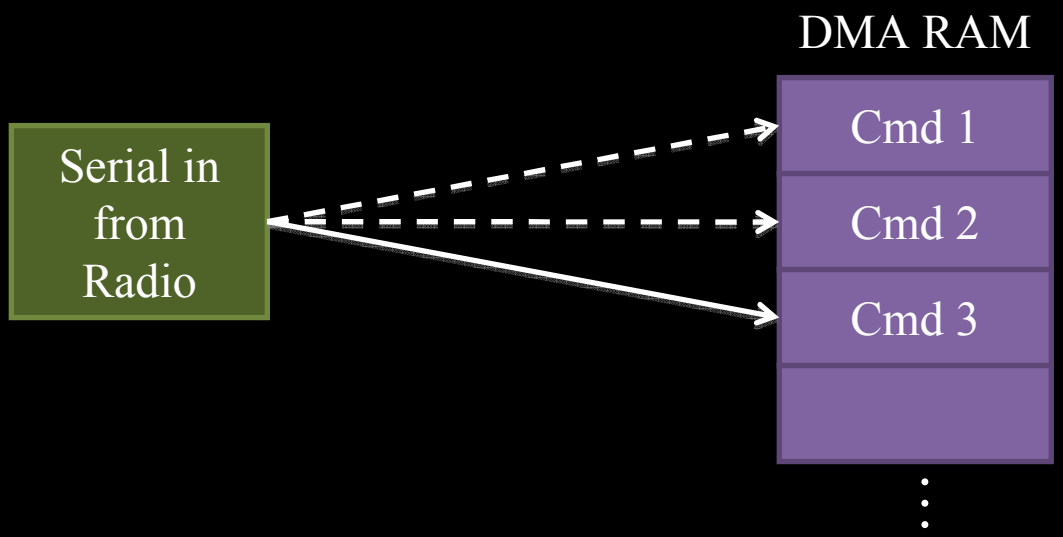
	0	1	2	3	4	5	6	7
0		STE	TX	STE		STE	TX	STE
8	HSK	STE	TX	STE		STE	TX	STE
16	TM	STE	TX	STE		STE	TX	STE
24	CMD	STE	TX	STE		STE	TX	STE
32		STE	TX	STE		STE	TX	STE
40	PWR	STE	TX	STE		STE	TX	STE
48	SSR	STE	TX	STE		STE	TX	STE
56	MAG	STE	TX	STE		STE	TX	STE

Direct Memory Access (DMA)



- Sequential data moved between peripheral and RAM automatically
- No processor time required
- 2 KB of DMA RAM in dsPIC33

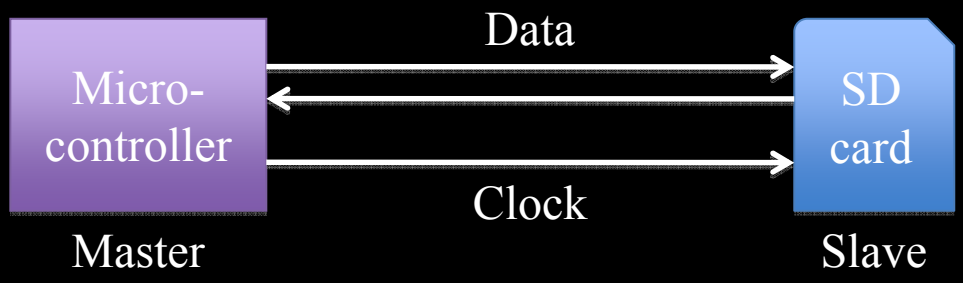
Serial and DMA

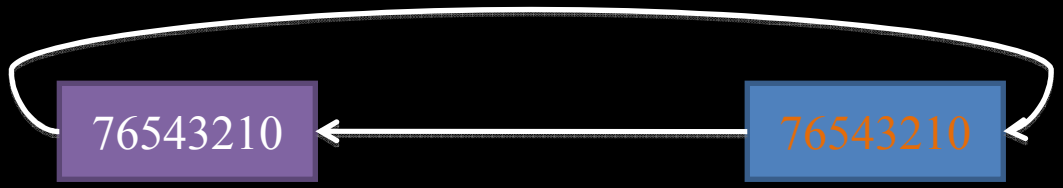


- Commands arrive quickly
- DMA replaces built-in serial buffer with RAM
- Operates independent of current task

Serial Peripheral Interface (SPI)

Inter-device shift register

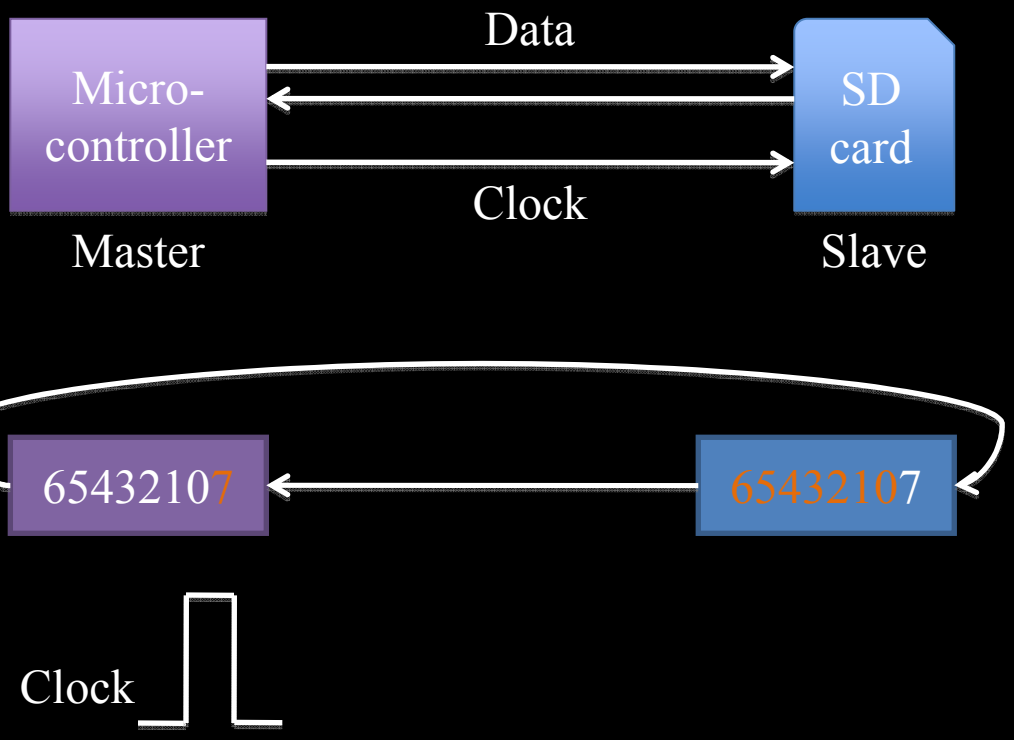




Clock

Serial Peripheral Interface (SPI)

Inter-device shift register



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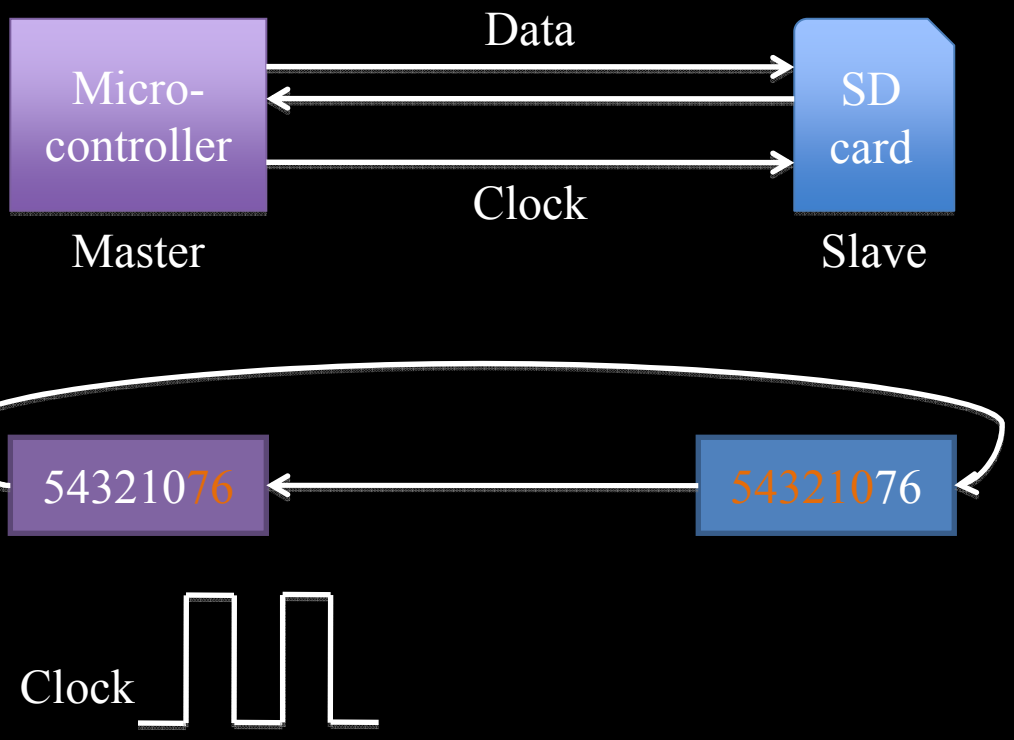

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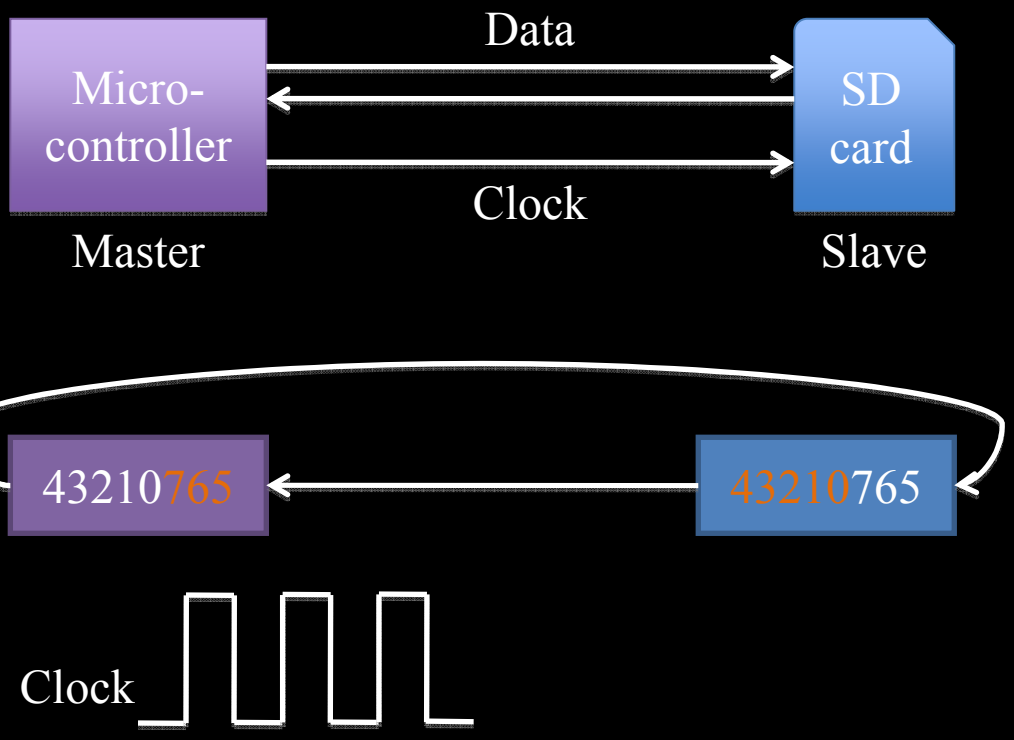

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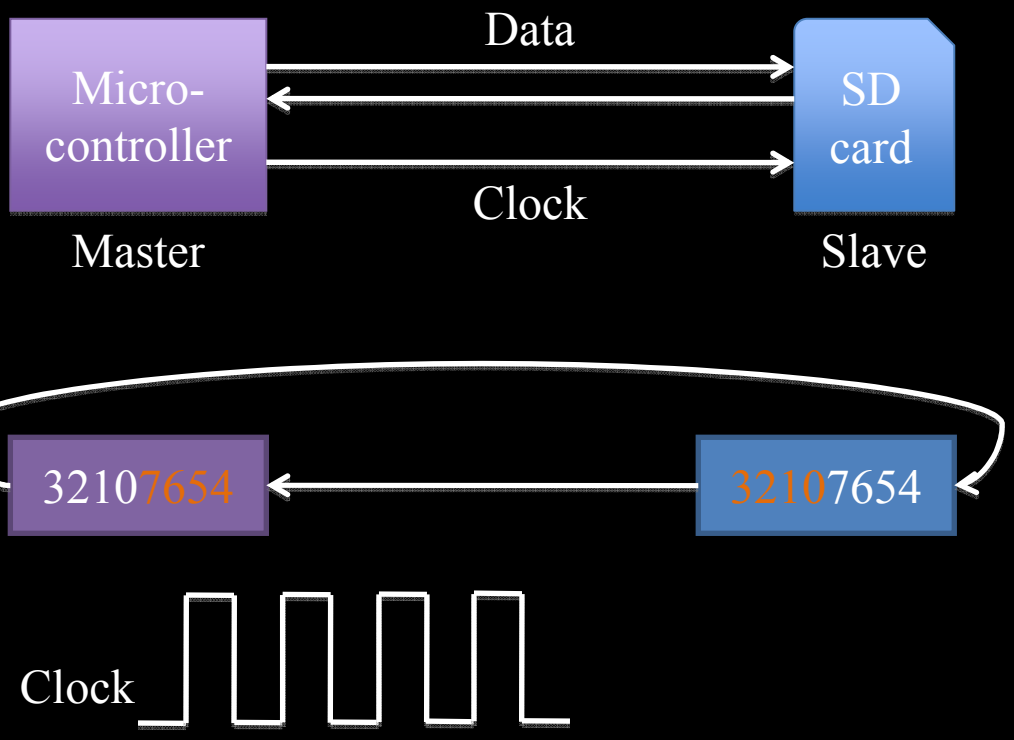

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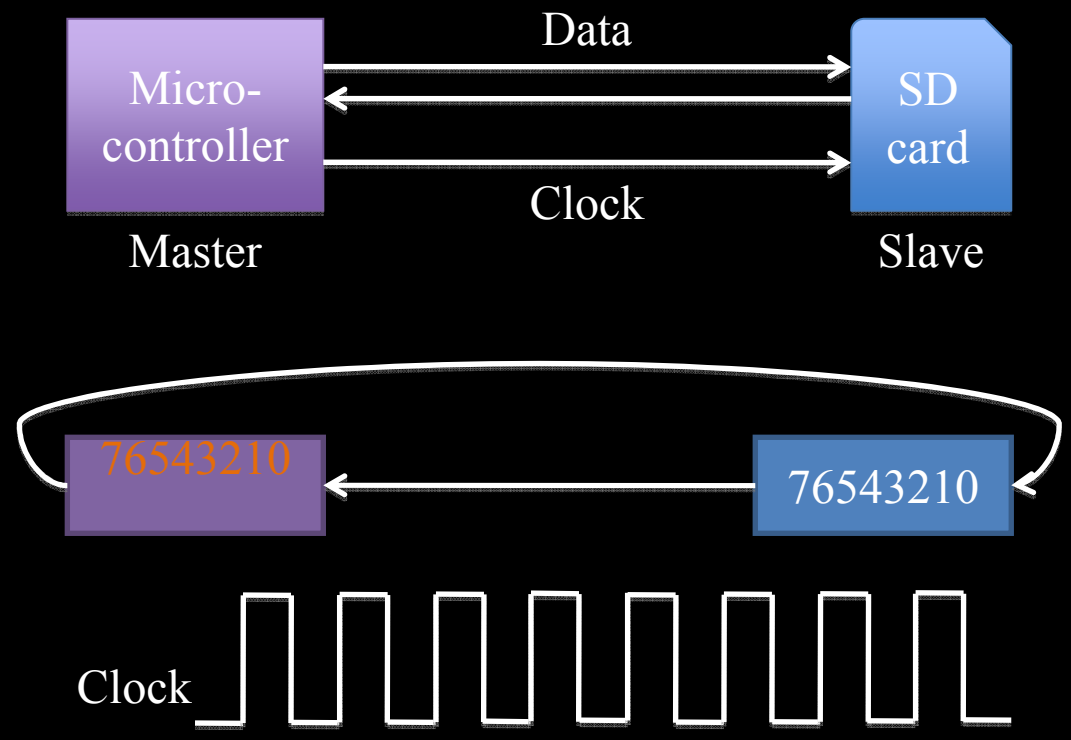
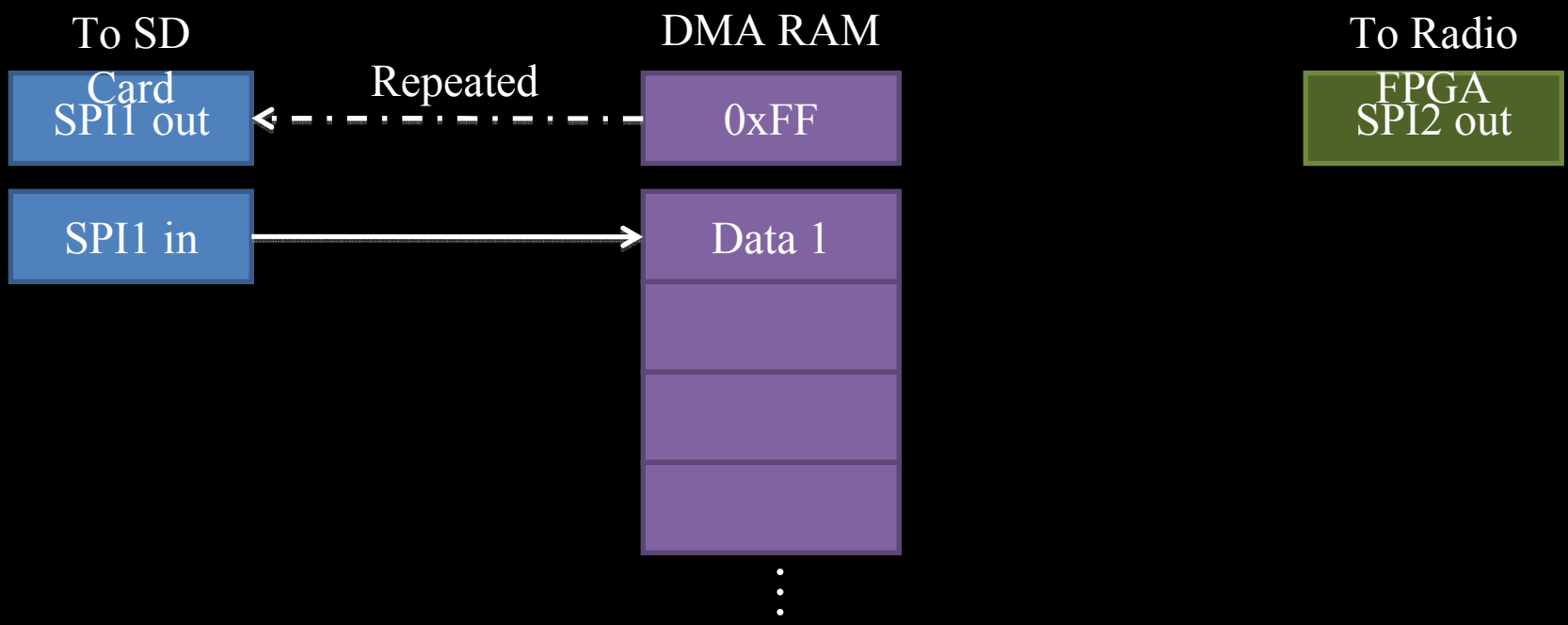
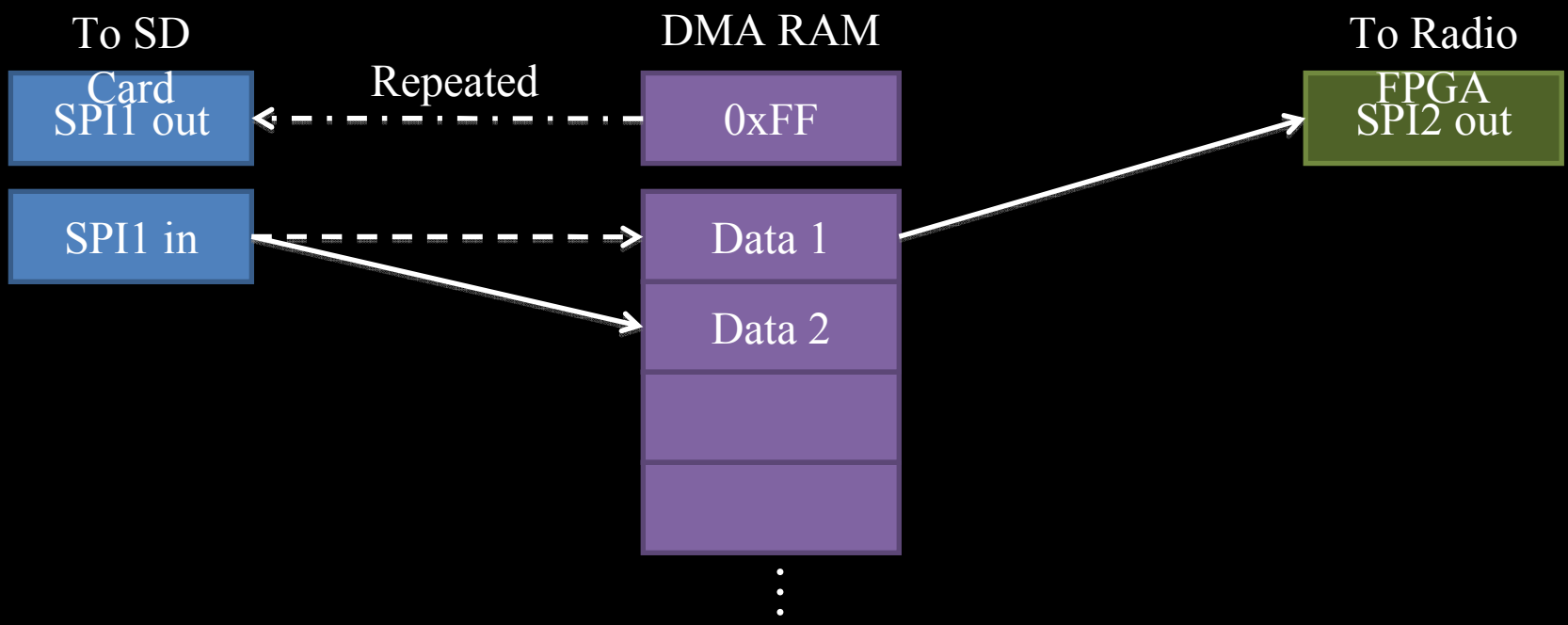


SPI and DMA



- SPI slaves need an input to produce output
- Entire transfer can be automated

SPI and DMA



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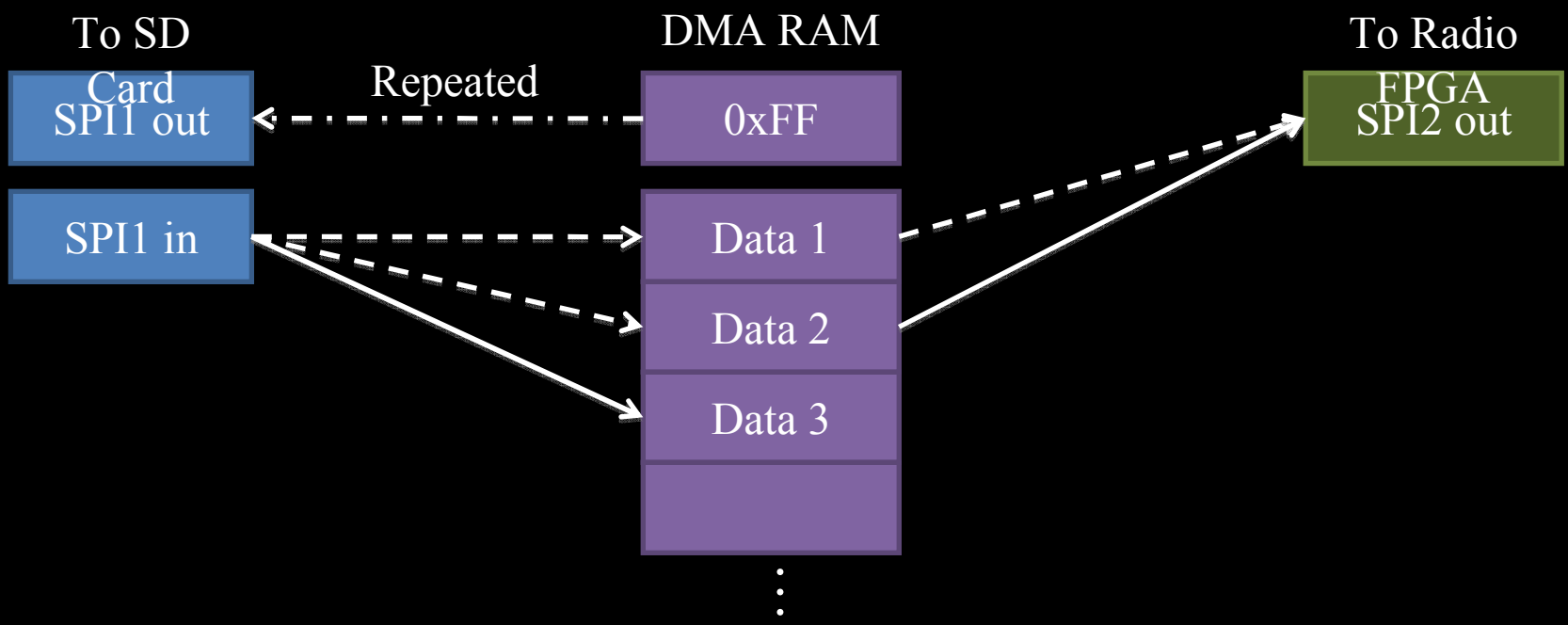
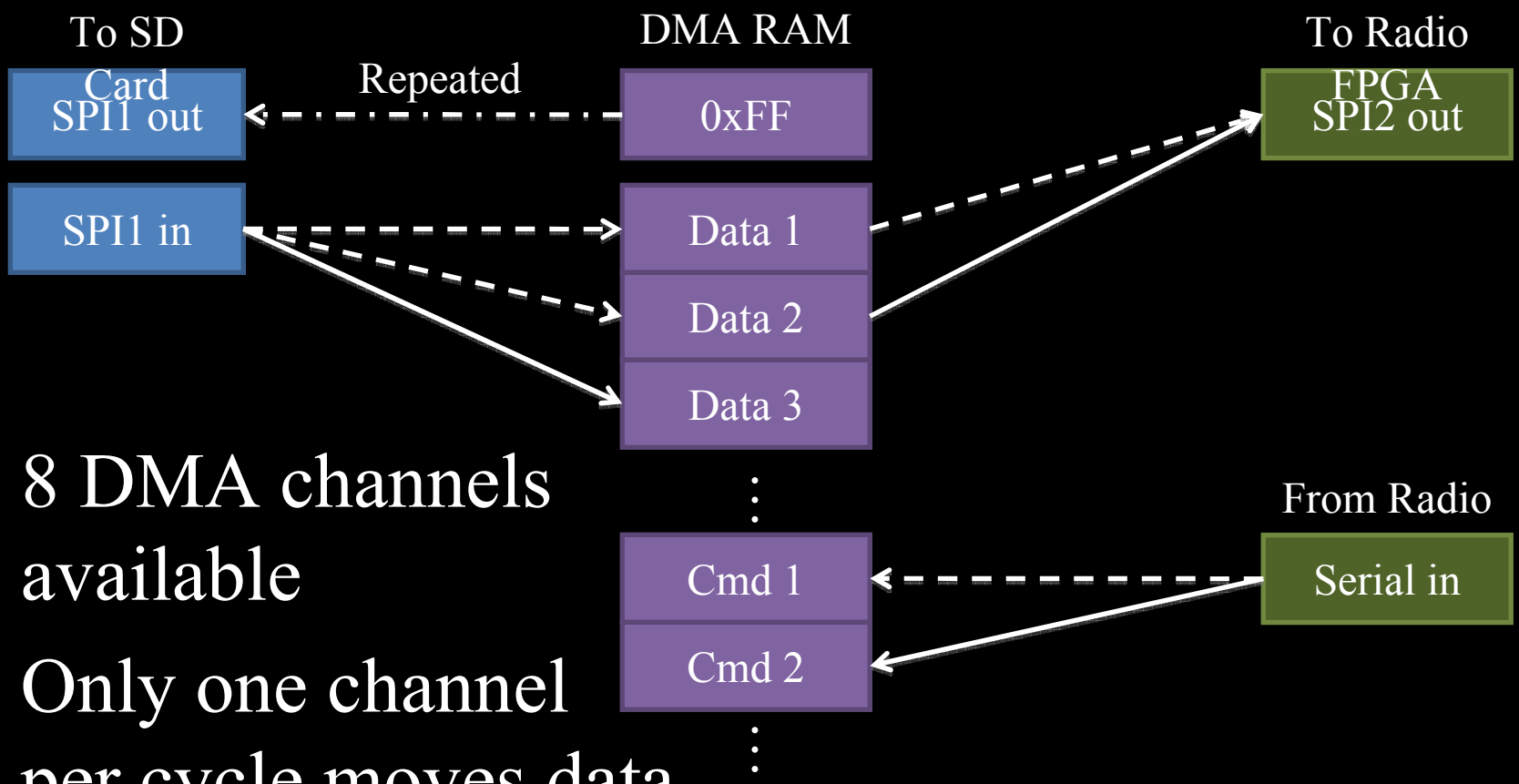
SPI and DMA



- SPI slaves need an input to produce output
- Entire transfer can be automated

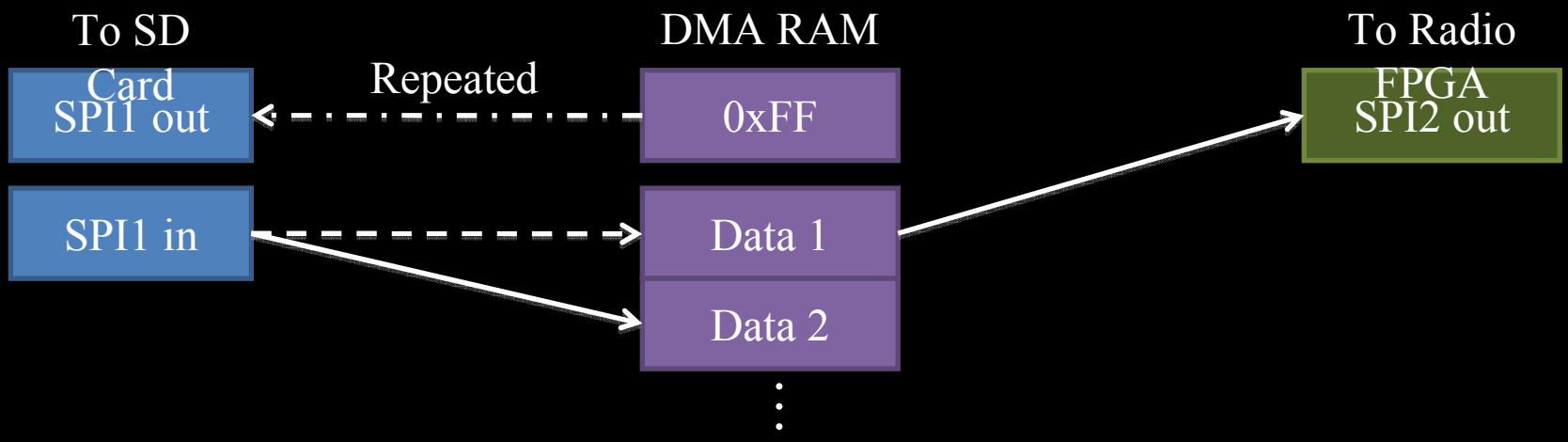
More DMA Channels



- 8 DMA channels available
- Only one channel per cycle moves data

Fudging the rules with DMA

- Combination of DMA with Background Task Table lets background task actions continue after task returns
- Transmit task could set up DMA and return



Fudging the rules with DMA

- No conflict concerns due to fixed schedule
- Next task is known, can be programmed to avoid conflict
- STE follows TX

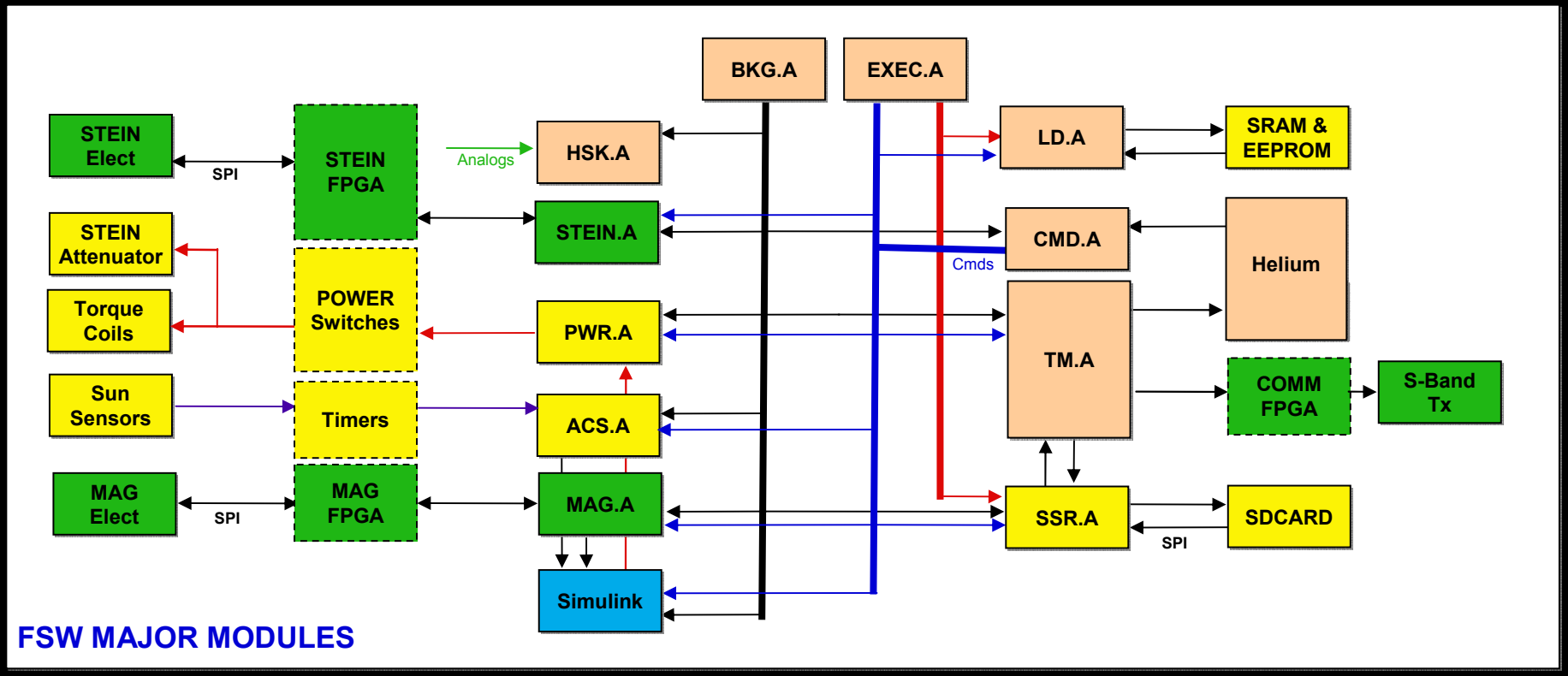
	0	1	2	3	4	5	6	7
0		STE	TX	STE		STE	TX	STE
8	HSK	STE	TX	STE		STE	TX	STE
16	TM	STE	TX	STE		STE	TX	STE
24	CMD	STE	TX	STE		STE	TX	STE
32		STE	TX	STE		STE	TX	STE
40	PWR	STE	TX	STE		STE	TX	STE
48	SSR	STE	TX	STE		STE	TX	STE
56	MAG	STE	TX	STE		STE	TX	STE

The Average Case

- Particle flux peaks should be rare
- Downlink capacity is ~8 Kbps average
- STEIN output thus limited, may be attenuated
- Other sensor inputs <1 Kbps

Ability to handle 2 megabit data flows will be infrequently used, but will prevent data loss

Flight Software Modules



Contacts

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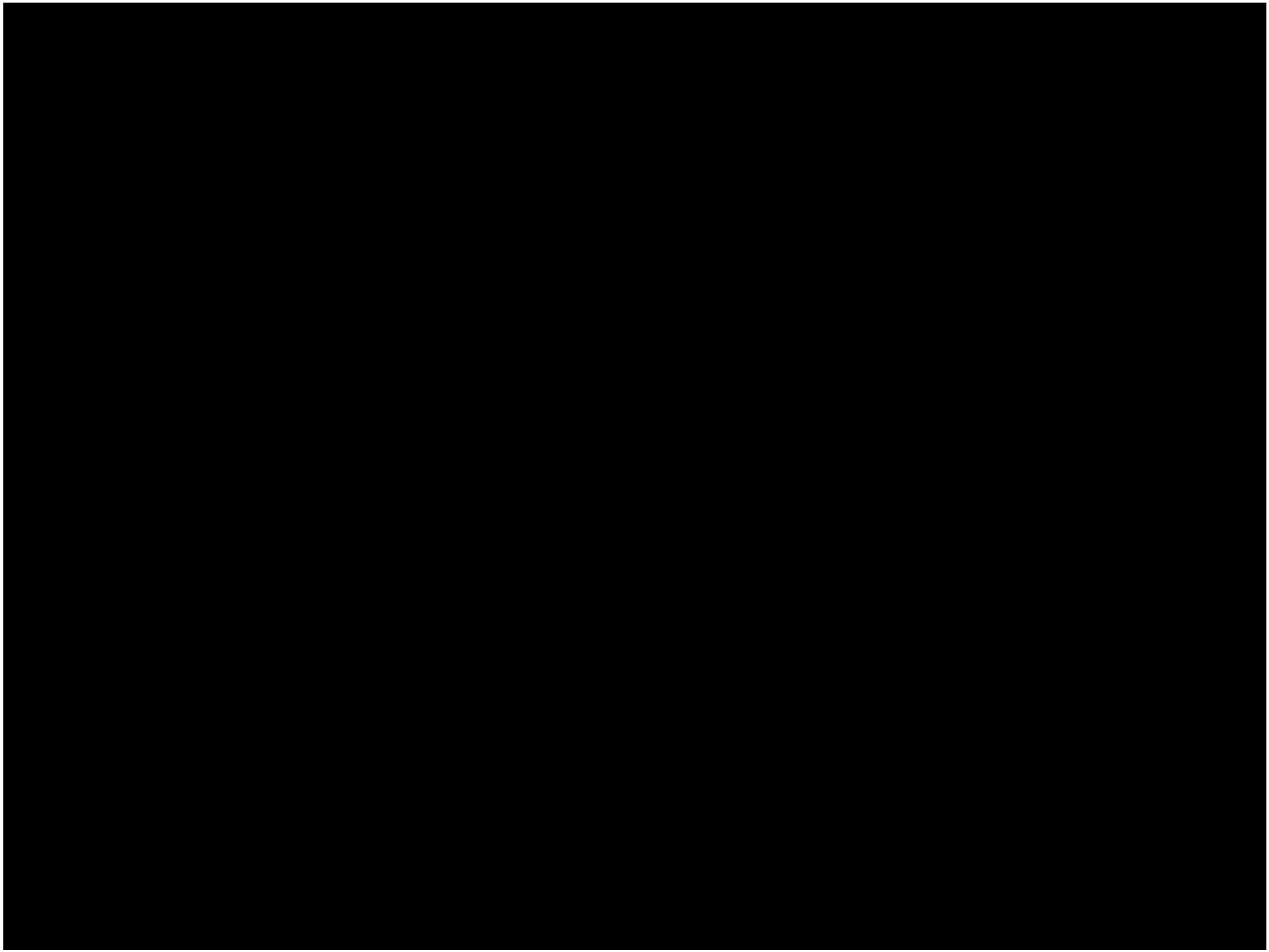
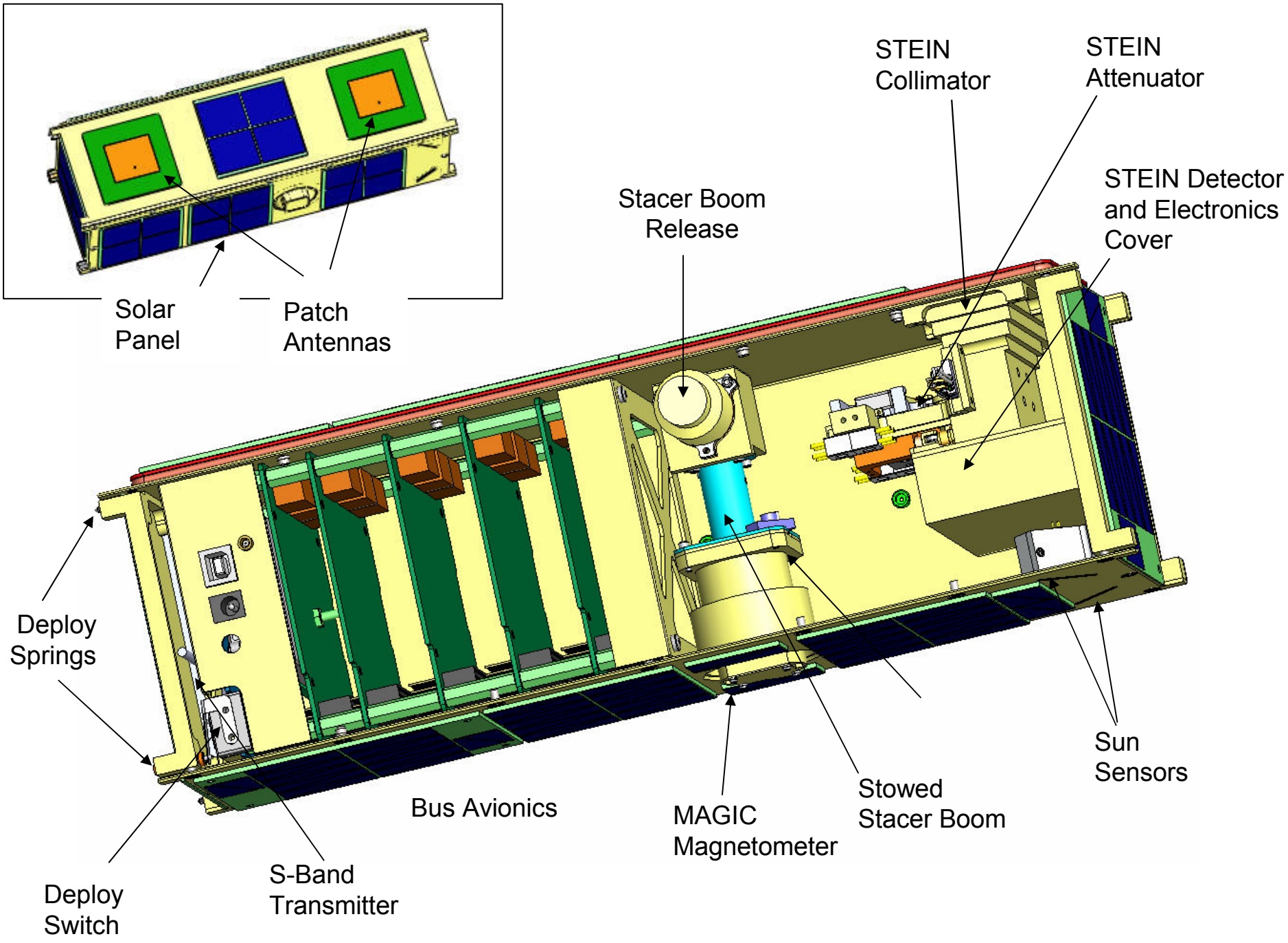
Science questions:

John Sample – jsample(at)ssl.berkeley.edu

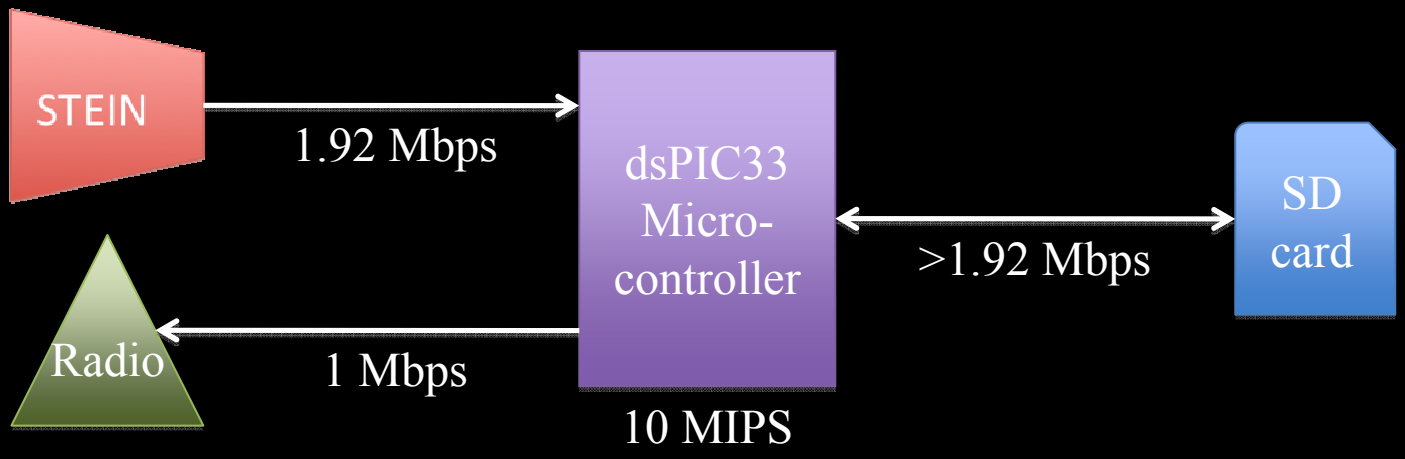



Solar Panel
Patch Antennas
STEIN Collimator
STEIN Attenuator
Stacer Boom Release
STEIN Detector and Electronics Cover
Deploy Springs
Deploy Switch
S-Band Transmitter
Bus Avionics
MAGIC Magnetometer
Stowed Stacer Boom
Sun Sensors

Even Better Multitasking

- DMA makes simultaneous data streams easier
- Communication routines can be simplified or do other work (e.g. CRC)

Maximum Data Rates



- STEIN: 120K particles/sec peak, 16 bits/particle
- All data stored on SD card; must handle peaks
- RF downlink: 1 Mbps constant
- 10 MIPS processor limit (power consumption)

Data Flow Requirements

- 10 MIPS limit due to power demand
- Must send or get 1 byte every 31.25 cycles
- Includes handshaking, SD card busy time, pointer updates, all other tasks

Background Task Scheduling

- 512 bytes takes 0.8 ms to move with SPI
- Run background tasks at 1024 Hz
- Tasks must finish in allotted time

	0	1	2	3	4	5	6	7
0		STE	TX	STE		STE	TX	STE
8	HSK	STE	TX	STE		STE	TX	STE
16	TM	STE	TX	STE		STE	TX	STE
24	CMD	STE	TX	STE		STE	TX	STE
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40	PWR	STE	TX	STE		STE	TX	STE
48	SSR	STE	TX	STE		STE	TX	STE
56	MAG	STE	TX	STE		STE	TX	STE

DMA and SPI

Stuff I need to know

- What's the real peak sample rate of STEIN? 80K flat or 30K/detector * 4 detectors? (it's the 120000)
- Switch slides 7,8
- Acronym explanation is good
- FIFO, SPI
- STEIN diagram?
- Block diag
- What have others done?
- 7min current; slow down
- SD card
- CINEMA specs/capabilities
- Why: detect solar particles, test ACS ability, show that students can do things, etc. Look at proposal, Glaser's presentation last year
- Credit people