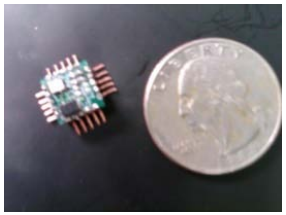
A Plug-and-play Approach Based on the I²C Standard

SPA on a Shoe-string



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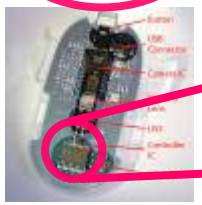
Outline

- A space-plug-and-play architecture (SPA)
- International collaboration
- Why SPA-1?
- The mini-PnP/SPA-1 protocol
- Using mini-PnP/SPA-1
- State of mini-PnP/SPA-1 development
- Mission concepts
- Conclusions

A space-plug-and-play architecture (SPA)

“platform”

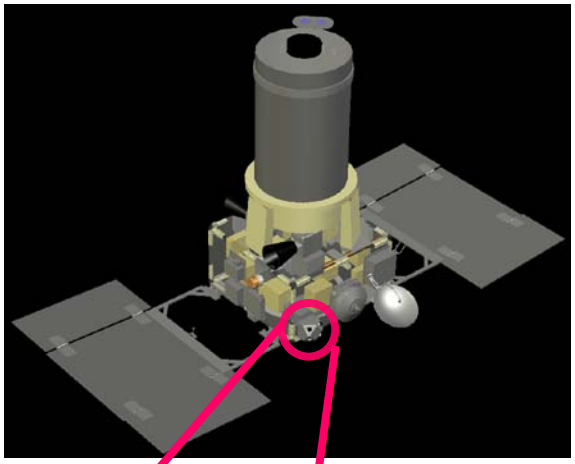
plug-and-play component



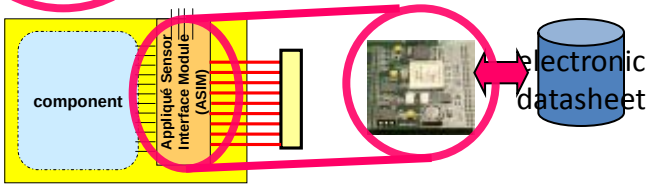
driver

USB interface chip

“platform”



plug-and-play component



appliqué sensor interface module (ASIM)

SPA as a *brand* of PnP

- Every component is a “black box”
  - Self-describing (using electronic data sheets)
  - Single-point interfaces (power,data,sync)
- Connect them to form a network
- They communicate with messages
- The network understands components and how to put them together automatically (self-organizing)

Benefits of SPA

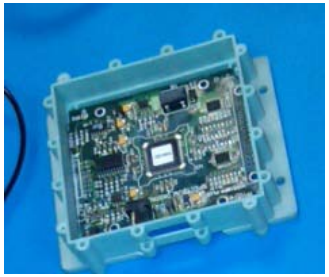
- Dramatic reduction in system development timeline
  - Simplification of Effort in integration and test
  - Promotion of component and software re-use
- Increase openness and ease of software development (all spacecraft data exposed) – “satellite as a desktop”
- Increased industry competition for components through open intelligent interfaces
- Additional robustness / resilience (a la carte redundancy)
- Late-point additions / graceful accommodation of requirement changes
- Future-proofing: Focus on invention and creation of missions, not the “tyranny of interface”

Learn more about SPA tonight at the Space Dynamics Laboratory!

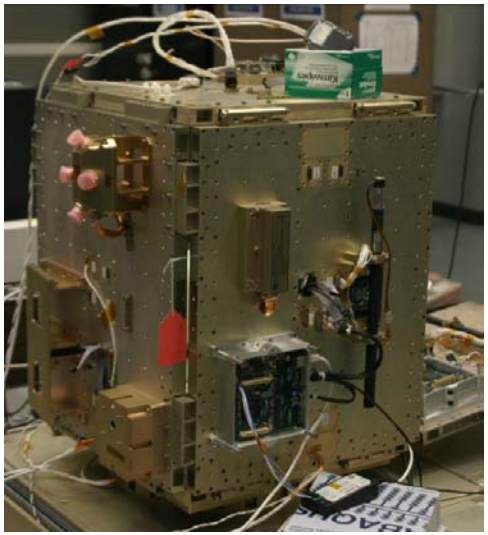
Gen 1 ASIM

Where is SPA?

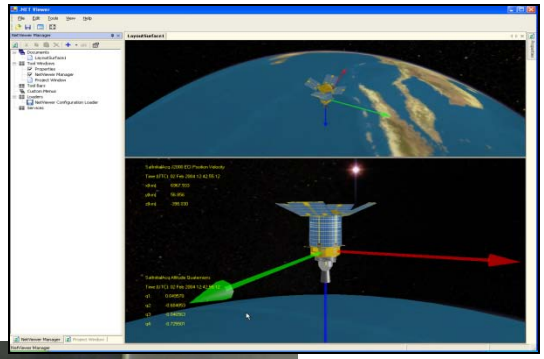
- Interfaces
- Tools
- Components
- Satellites
- Flight heritage
  - Sounding rocket
  - Orbiting on TacSat 3



Gen 2 ASIM

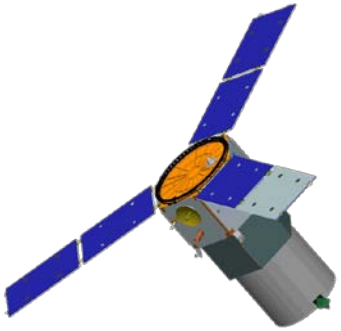


PnPSat 1

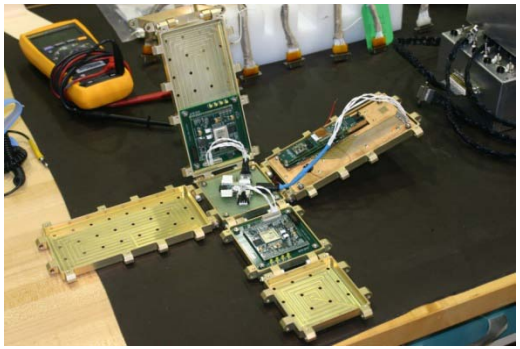


Spacecraft Design Tool

PnPSat 2



Tacsat 3



CubeFlow

International collaboration Nanosatellite And Pnp Architecture (NAPA)

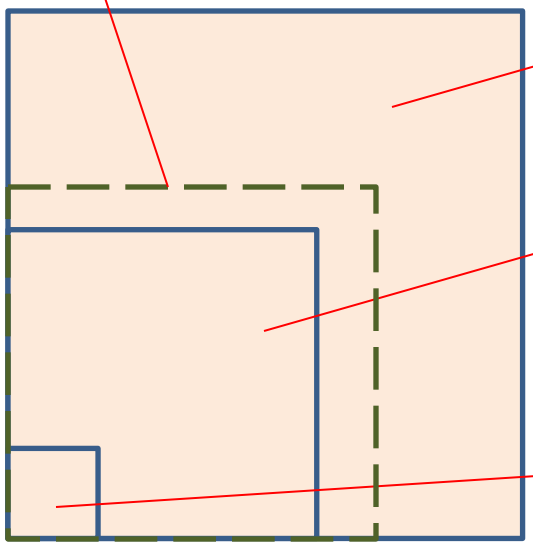
- USAF and FMV signed program agreement* August 2009
- Primary objectives
  - Harmonize plug-and-play approaches of the two nations
  - Establish joint testbeds for exchange of PnP components
  - Demonstrate interchangeability between testbeds
- Early findings
  - SPA architecture represented common approach
  - Concluded that a “minimalistic” version was needed
  - Led to pursuit of “mini-PnP” technology as joint effort
    - Mini-PnP is a generic plug-and-play technology (similar to USB)
    - SPA-1 is a form of mini-PnP suitable for space

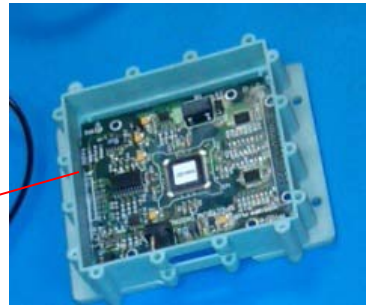
**Bi-lateral Project Agreement (PA-TRDP-US-SW-AF-09-002).*

Why SPA-1?

- Nanosatellites are least able to tolerate overhead in interface components
- One size does not fit all…

size of cubesat face





SPA-S
75 mm body size
< 1500 mW
< 300,000 kbps

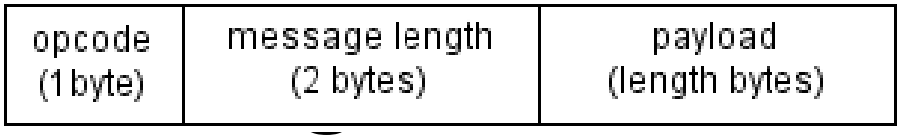
SPA-U (-S option)
50 mm body size
< 1000 mW
< 1000 kbps

TARGET FOR SPA-1

The mini-PnP (MP)/SPA-1 protocol

- We sought the simplest possible electrical interface – chose I^2C (few wires, multidrop, simple state machines, ubiquitous)
- The choice left us “only” to decide what to do above the physical layer
- Many protocols for I2C have been developed (SMbus,ACPI), none “plug-and-play”
- Team jointly created generic (non-space-specific) protocol for I^2C (“mini-PnP”) as open source (non-ITAR) protocol (space-qualified version – SPA-1 – created in US would be subject to ITAR)

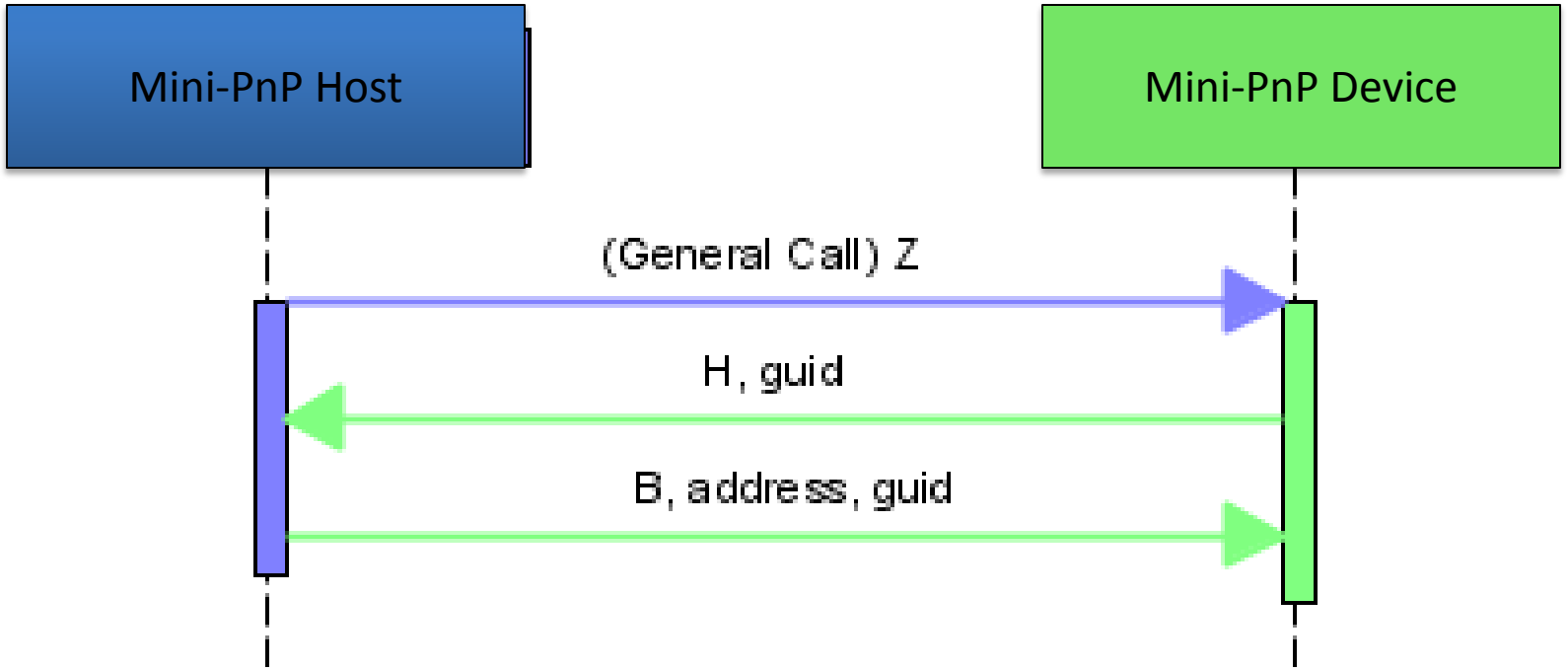
MP/SPA-1



Commands (opcode)	Responses (opcode)
Self test	Status
Reset	Data
Initialize	xTEDS
Request version	xTEDS & PID
Request xTEDS	Version
Request data subscription	Hello
Cancel data subscription	
Power on	
Power off	
Command	
Time at tone (SCET)	
General call for registration	
Update address	
Ack	
Not Ack	

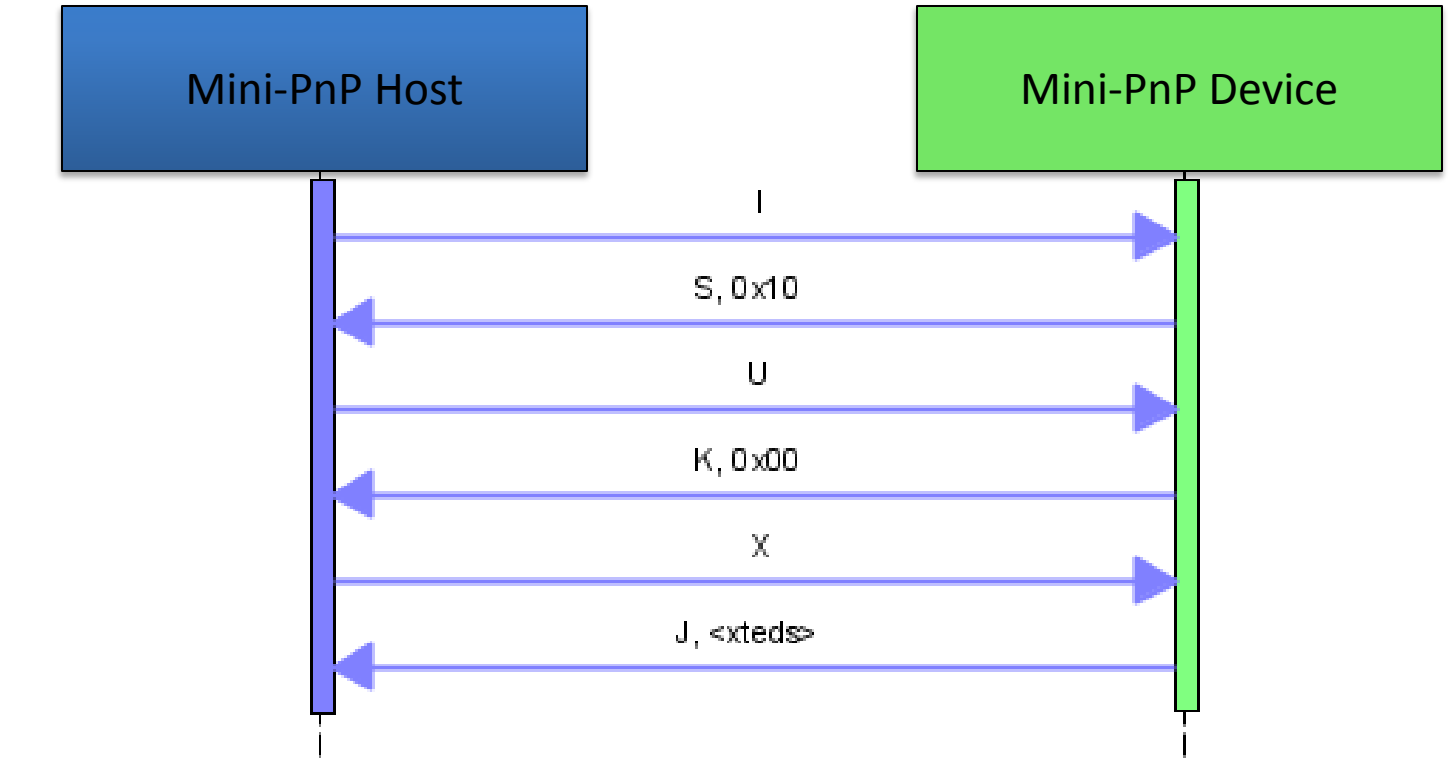
Mini-PnP/SPA-1 Address resolution

- All mini PnP devices have unique global identification (guid)
- Implement address resolution by performing a ”general call”
- All devices use 0x11 as an initial address
- Devices become multi-master and ”walk up” address space until they find an open spot and claim it



Mini-PnP/SPA-1 Electronic Data Sheet (xTEDS*) registration

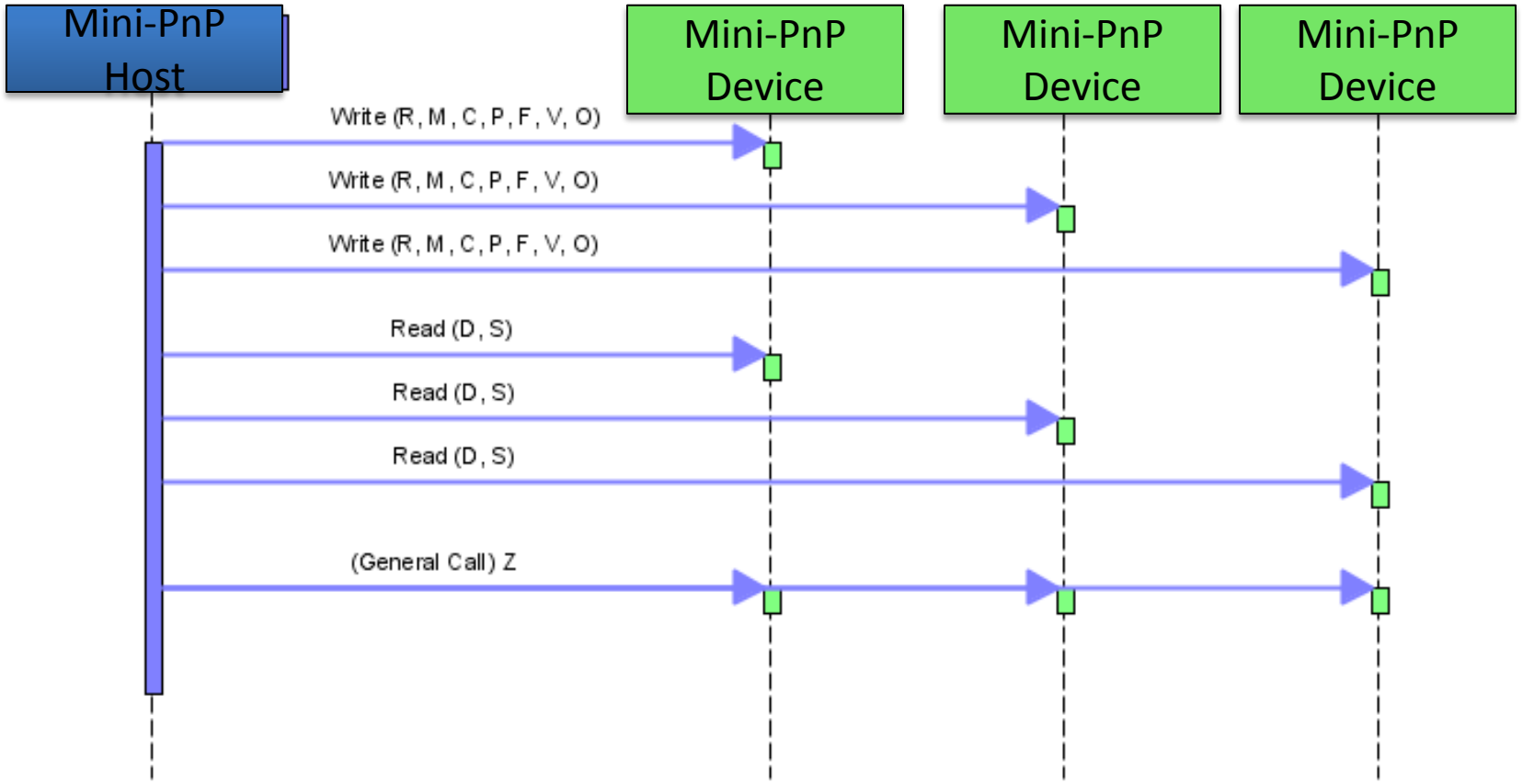
- Mechanism defined to permit the extraction of electronic datasheets from mini-PnP device
- Host parses xTEDS* and registers device services for use by other devices and applications



* *XTEDS = eXtensible Transducer Electronic Datasheet*

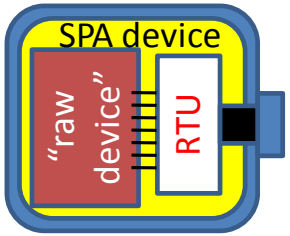
Mini-PnP/SPA-1 Round Robin communication

- Mini-PnP Implements a Command (”write”), Response (”read”), and General Call as a continuous cycle using a non-weighted round-robin, visiting all known devices and looking for new ones

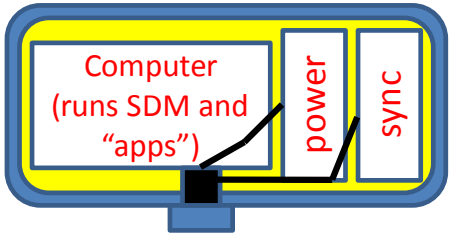


Using mini-PnP/SPA-1

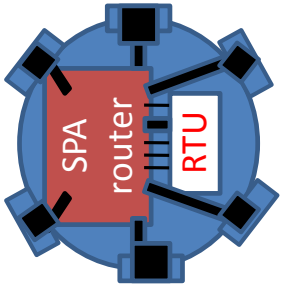
Building spacecraft with SPA: you'll need



components…

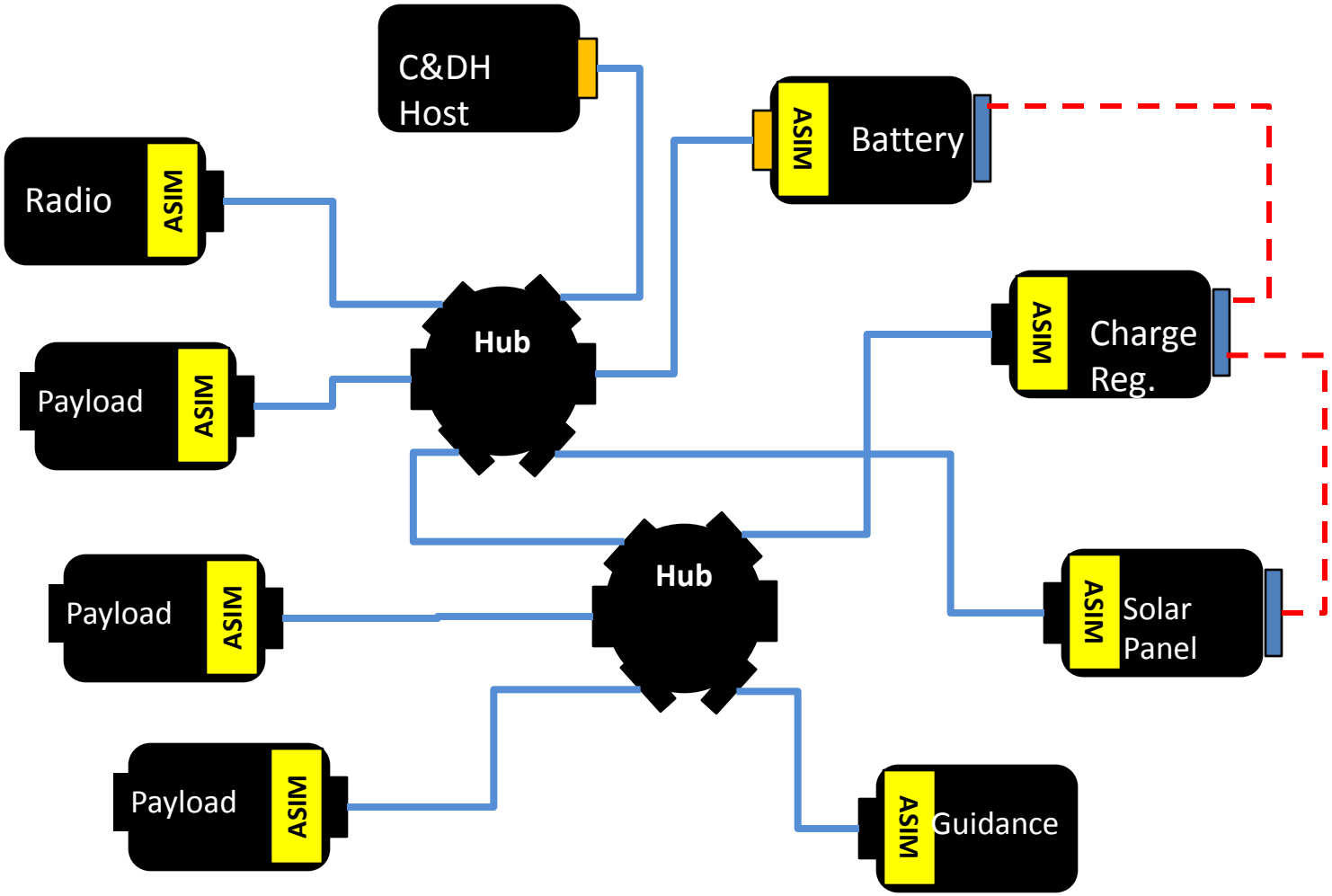


..at least one computer…



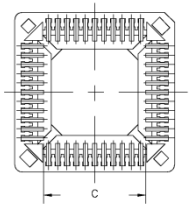
… and routers / hubs / switches (possibly)

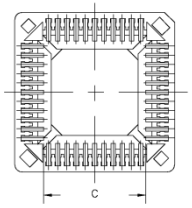
Connect together to form a spacecraft…



State of mini-PnP/SPA-1 development

1. 

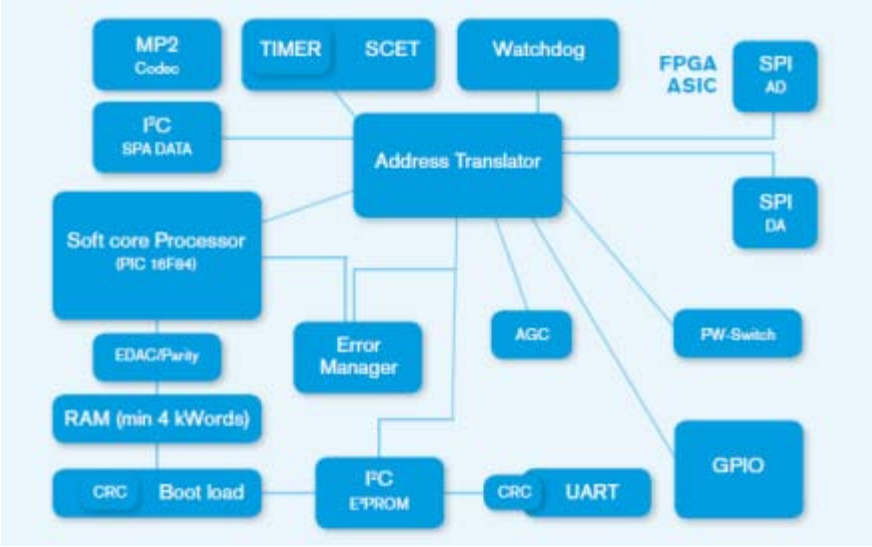
2. 

3. 

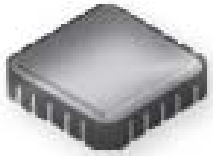
- ASIMs (US) / RTUs (Sweden) in development
  1. Low cost (~ 30$US) prototype / experimentation modules (mini-PnP)
  2. Pre-flight units (~100$US) cofired ceramic / QFN modules (10mm x 10mm) (quasi – SPA-1)
  3. Flight units (~??US) cofired ceramic / rad-hard / QFN modules (10mm x 10mm) (SPA-1)
- Other flight units / evaluation units with enhanced features available from AAC Microtec

Radiation Tolerant nano-RTU

- FPGA based
  - 20 kRAD SEU/SEE free using TMR, EDAC, parity and CRC
  - Fully pipelined PIC16 soft core (16F84) with 1 MIPS/MHz
  - In circuit/system programmable
  - Power consumption ~ 20-150 mW
  - PCB version (34 x 34 mm^2)
- Interface to low speed devices ~ 100 kbit/s (SPA-1)



SPA-1 RTU block diagram



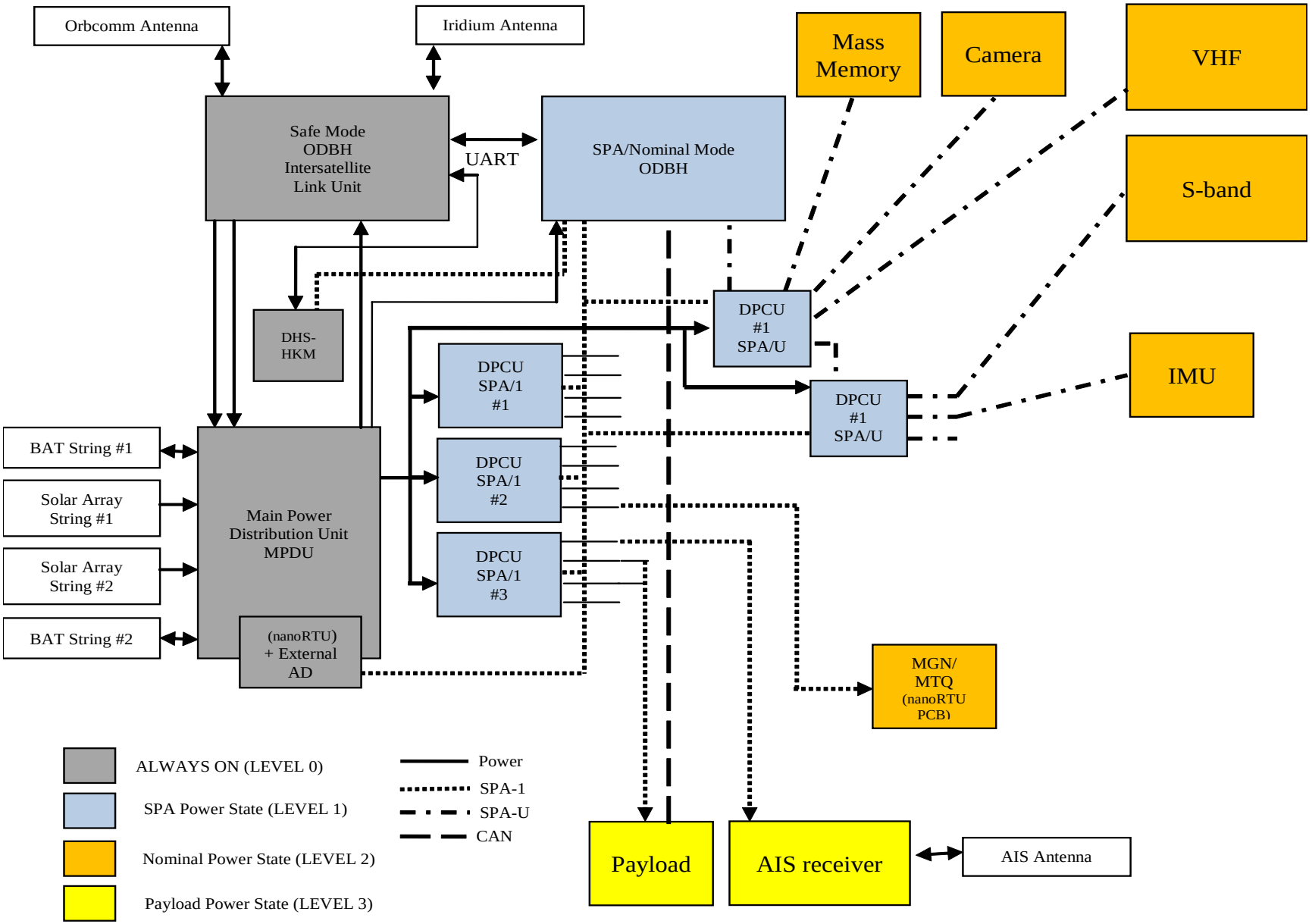
SPA-1 RTU (MCM)

SPA-1 RTU (board version)

Upcoming Work

- Continued development on mini-PnP and SPA modules and evaluation kits
- Flight project developments
  - RAMPART – mixed network of ASIM/RTU modules to study radiation effects
  - Trailblazer 1.5 – “simple-as-possible” exploratory cubesat (completely SPA-1 based)
  - QuadSat/PnP

System design example (QuadSat-PnP)



Conclusions

- The SPA Plug-and-play architecture offers a new model for rapidly and flexibly building spacecraft through intelligent modularity
- A joint US/Sweden program (”NAPA”) has developed improvements to SPA to allow simple spacecraft components to support plug-and-play
- The development of the generic minimalist protocol has been described
- The mini-PnP protocol will be open source / ITAR free, but space adaptation of mini-PnP (referred to as ”SPA-1”) results in ITAR restrictions (when performed in the US)
- AAC Microtec (Sweden) has created interface modules that implement mini-PnP in rad-tolerant form
- System design example has been described