HamSCI

A Modular SDR

for

HamSCI and Other Users

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HamSCI Workshop - Case Western Reserve University

March 22-23, 2019

A Few Quick Questions

Raspberry Pi Class SB Computer

How many do you own?

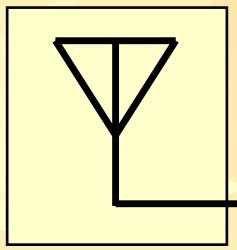
A Few Quick Questions

Raspberry Pi Class SB Computer

How many still in the box?

Let's Talk Architecture

Personal Space Weather Station



Mid-grade RX

14b ADC
122.88Msps

Mid-grade TX

14b DAC
122.88Msps

Server Data Engine

50K LE FPGA
5Gb/s USB 3.0
2x GbE

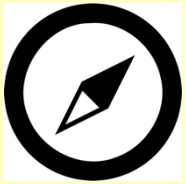
GbE
GbE

I2C
SPI
UART

GPSDO

Internet

Lo-speed Sensors



Client Computer
(Single Board or Desktop)

GbE

- Local User Display(s)
- Local Data Storage
- Local Data Reduction
- Processed Data to HamSCI Servers

HamSCI Public Database

Phase 4B Satellite Ground Station

Mid-grade RX

14b ADC
122.88Msps
Undersample

Mid-grade TX

14b DAC
122.88Msps
Baseband

Server Data Engine

50K LE FPGA
5Gb/s USB 3.0
2x GbE

I2C
SPI
UART

GbE
GbE

GPSDO

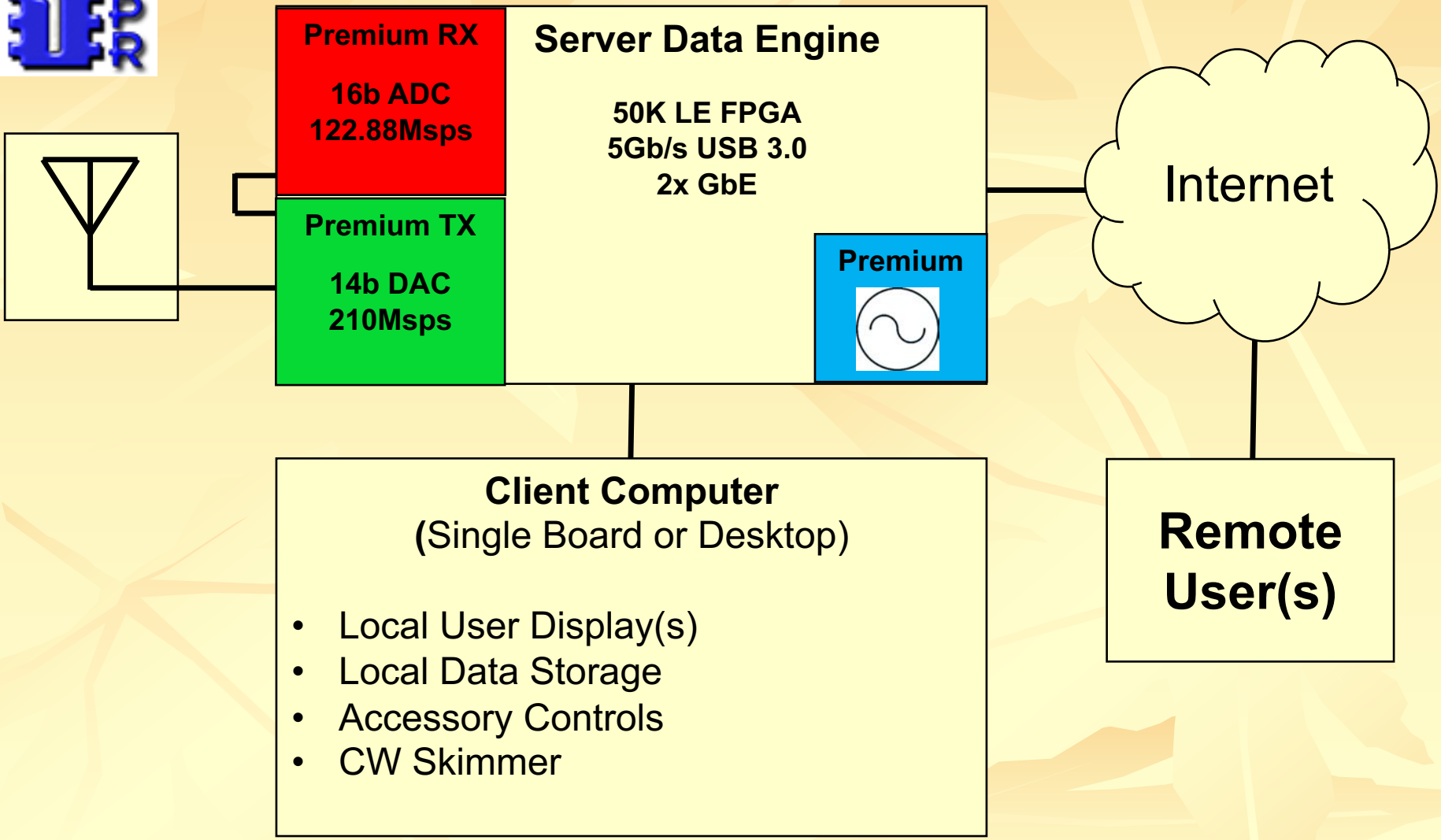
Internet

Client Computer
(Single Board or Desktop)

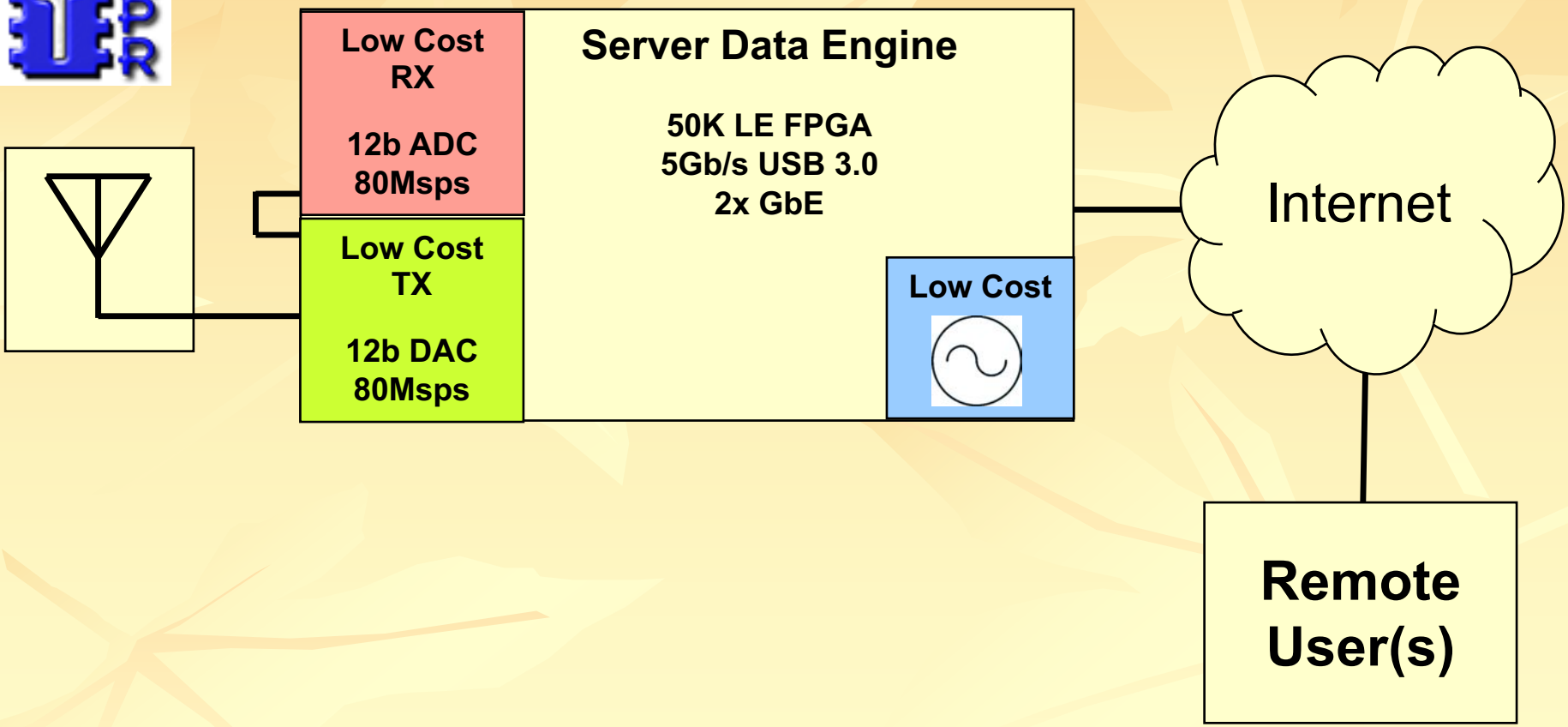
GbE

- Local User Display(s)
- Local Data Storage
- Channel allocation

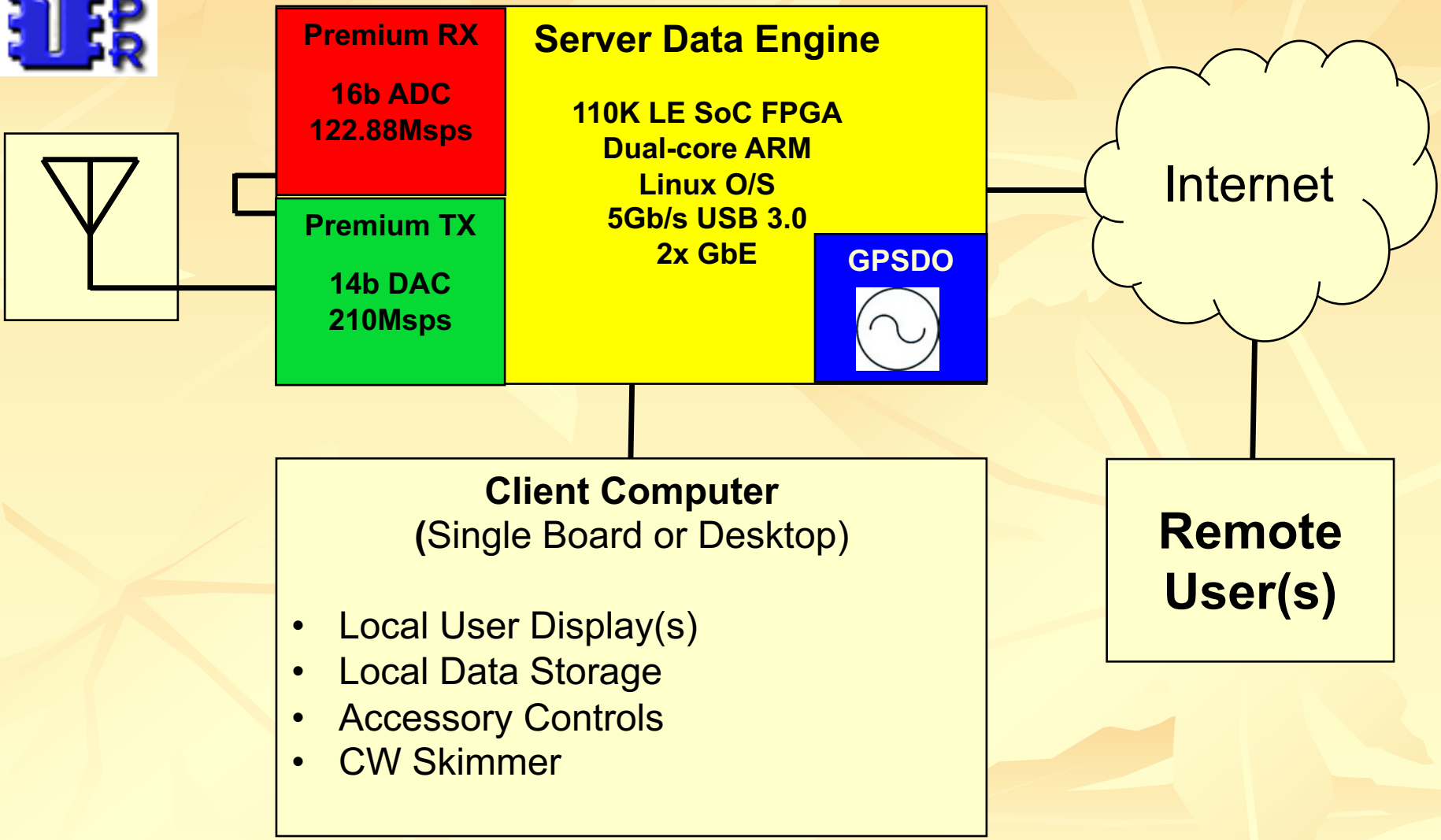
Amateur HF Experimenter



Low Cost Remote Radio



Premium Performance



So What Are We Going to Build?

Initial Considerations

It's All About Tradeoffs

- Cost
  - Affects user base: lower cost => more users
- Capability
  - Affects cost: more capability => higher cost
- Size of User base
  - Affects cost: more users => higher volume => lower cost
- Adaptability to Different Applications
  - Affects user base: more diverse uses => more users
- Expandability and Upgradability
  - Project lifetime: more expandable => future proof (to a point)

Initial Considerations

Cost

TNC2 was $179 in 1985, which is about $420 in 2019

Keep the cost as low as possible to keep the user base as large as possible

Goal:

Sell the user only the hardware needed for the intended task!

Initial Considerations

Capability

More capability means higher cost

Don’t over-design

Goal:
Offer multiple production options where feasible

Initial Considerations

User Base

Try to make the user base as large as possible

Large production lots means lower cost per unit

Goal:

Get the word out to as many prospective customers as possible.

Initial Considerations

Adaptability to Different Applications

The more different applications, the wider the user base

Goal:

Make the hardware versatile enough to be used for multiple applications

Initial Considerations

Expandability and Upgradability

The more expandable the hardware, the longer its useful lifetime before becoming obsolete

This only works to a point, especially in today's climate of rapid progress

Goal:

Make the hardware architecture upgradable to keep pace with advances in the state of the art

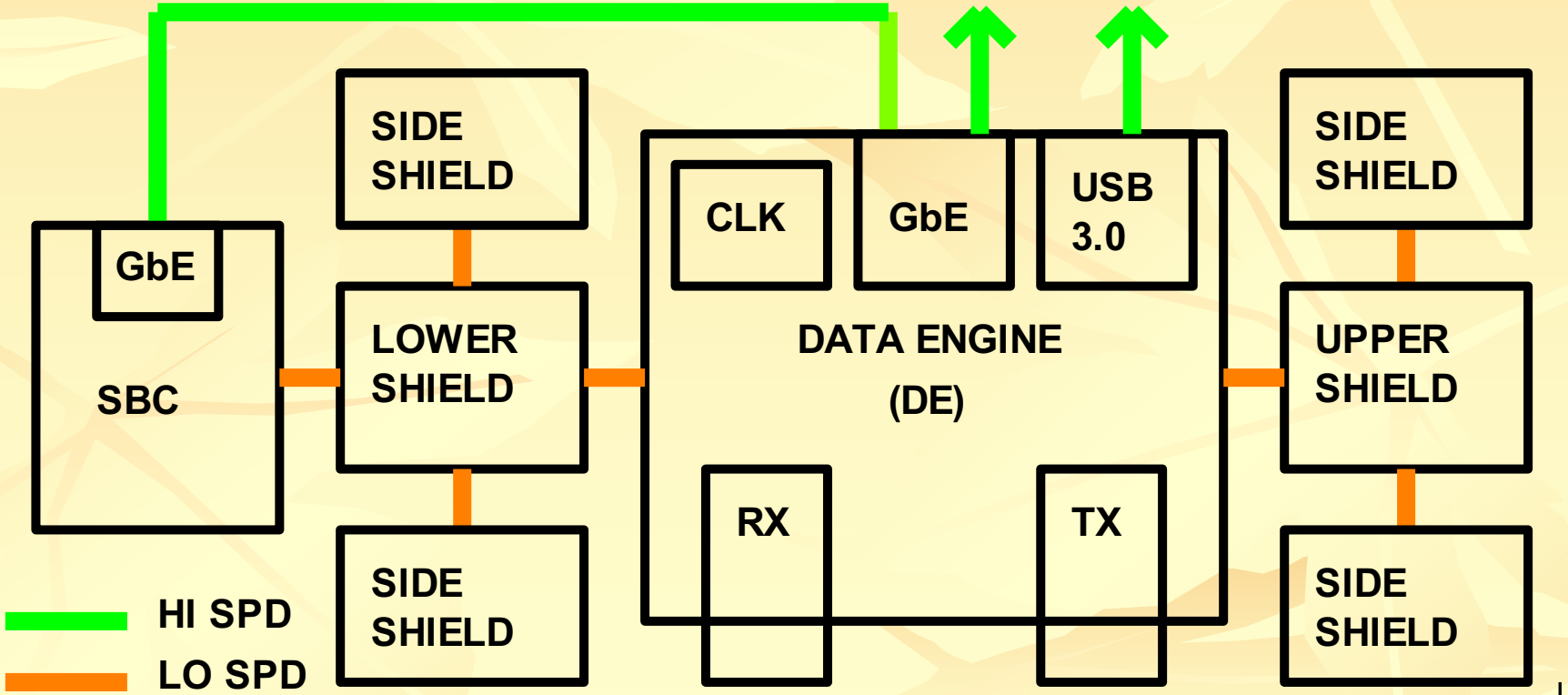
Initial Considerations

To Summarize

- Keep the cost below $500, less if possible
- Offer production options to better match the hardware to the user's application
- Spread the word
- Design architecture to target multiple applications
- Design architecture for expandability

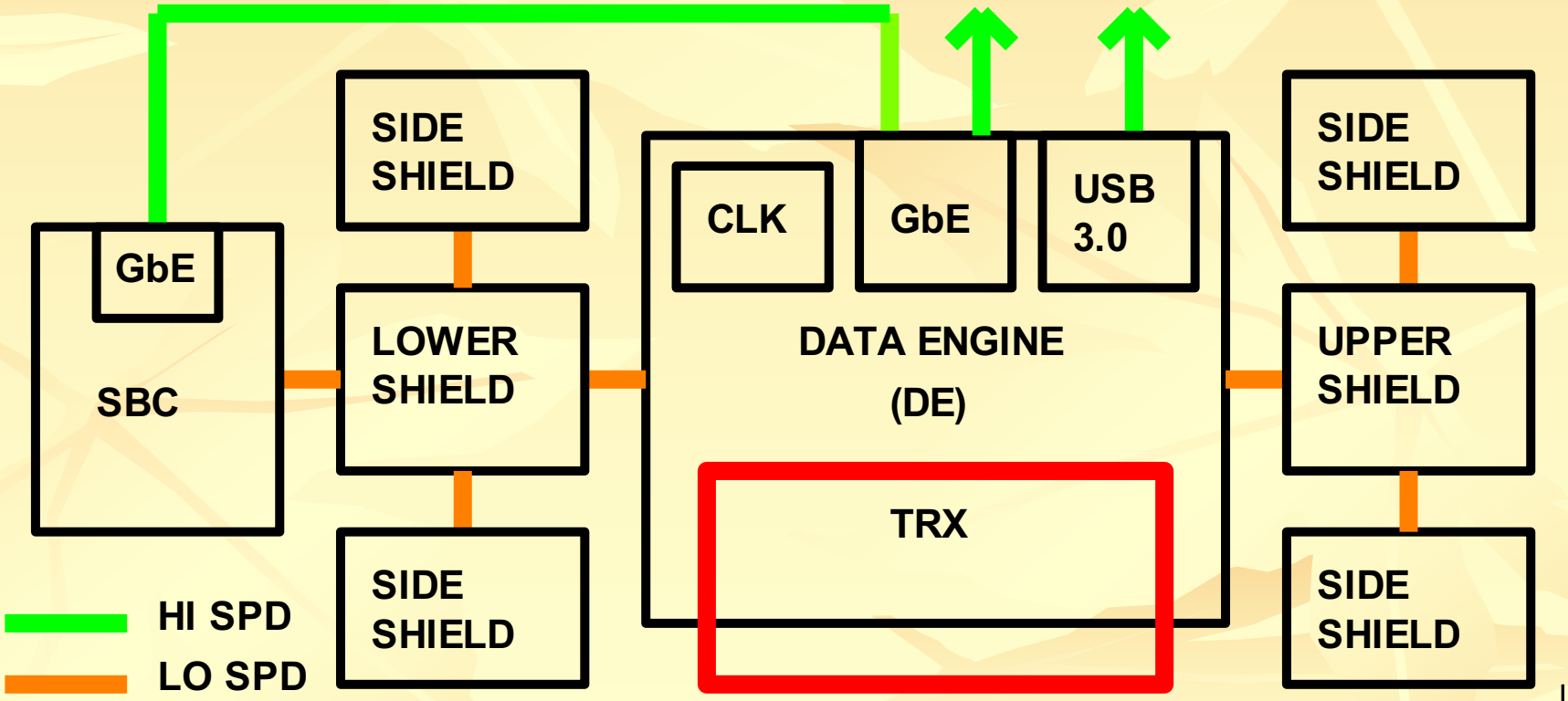
System Architecture

Proposed Modular Solution

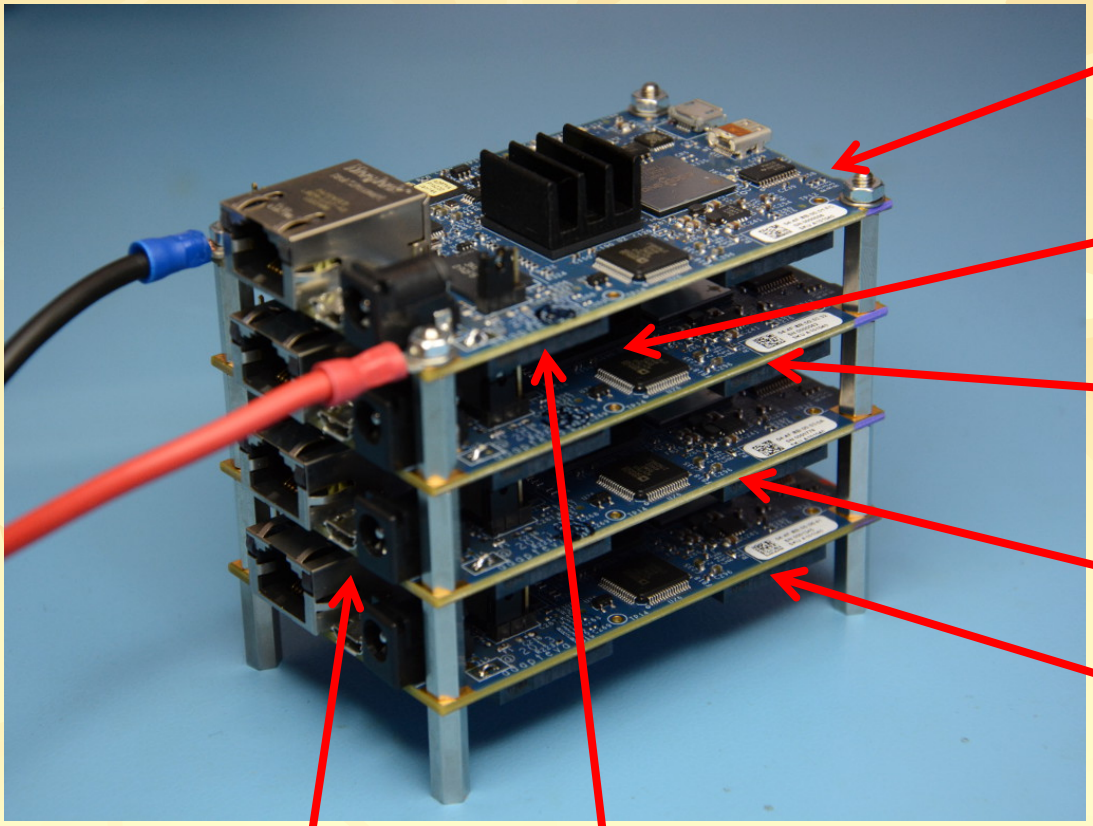


System Architecture

Proposed Modular Solution



System Architecture



uber (top) Shield

RF Modules go here

Data Engine

unten (bottom) Shield

SBC

neben (side) Shields go here (all 4 sides)

HamSCI
http://hamsci.org

System Architecture

Production Options

- Three versions of Data Engine (DE)
  - **Entry Level (low cost)**
  - **Basic Level (moderate cost, mainstream capability)**
  - Advanced Level (highest cost, most capable)

- Many Versions of RX, TX and TRX boards
  - **SWS RX (HF Receiver, 100kHz – 60MHz)**
  - P4G RX and TX or single TRX (5G TX, 10G RX)
  - Experimenter (70MHz – 6GHz MIMO TRX)

System Architecture

Target Applications

- HamSCI Space Weather Station (SWS)
- Phase 4 Satellite Ground Station (P4G)
- Academic uses to teach SDR and FPGA techniques
- Amateur Communications SDR
- Experimenters' (Amateur and non-Amateur) SDR
- Remote Ham Radio
- Others?

System Architecture

Expandability

- All RF Modules will work with all DEs
  - Subject to the DEs hardware limitations
- Custom configurations may require custom code
- Need more horsepower? Replace just the DE
- Need extended frequency range? Replace the RF module(s)
- Build an SWS, then change to a P4G station without starting over

What's In a Name?

First Things First

- Everyone needs a catchy name
  - Lime SDR
  - Raspberry Pi
  - Orange Pi
  - Banana Pi
  - Red Pitaya
  - Graperain

What's In a Name?

Orangesicle

IT'S

- Summertime Defined
- Fruity
- Delicious
- Nostalgic
- Orange!

Orange is the new black!

(And yes, Virginia, we *can* get orange solder mask)

Hardware Features

Orangsicle Data Engine Types

- Three initial versions of Data Engine (DE)
  - **Entry Level (low cost)**
  - **Basic Level (moderate cost, mainstream capability)**
  - Advanced Level (highest cost, most capable)

Entry Level and Basic Level can use the same PC Board!

(If we are careful designers!)

Hardware Features

Entry Level DE Features

- Altera/Intel 10M50DAF256C8G FPGA **50K LEs**
- 11-15V wide input, low noise SMPS
- 3-port GbE Switch (Dual GbE data interfaces)
- 128Mx4bit QSPI Flash memory
- Temperature sensor
- Power-on reset monitor, fan header

Hardware Features

Entry Level DE Features, cont'd

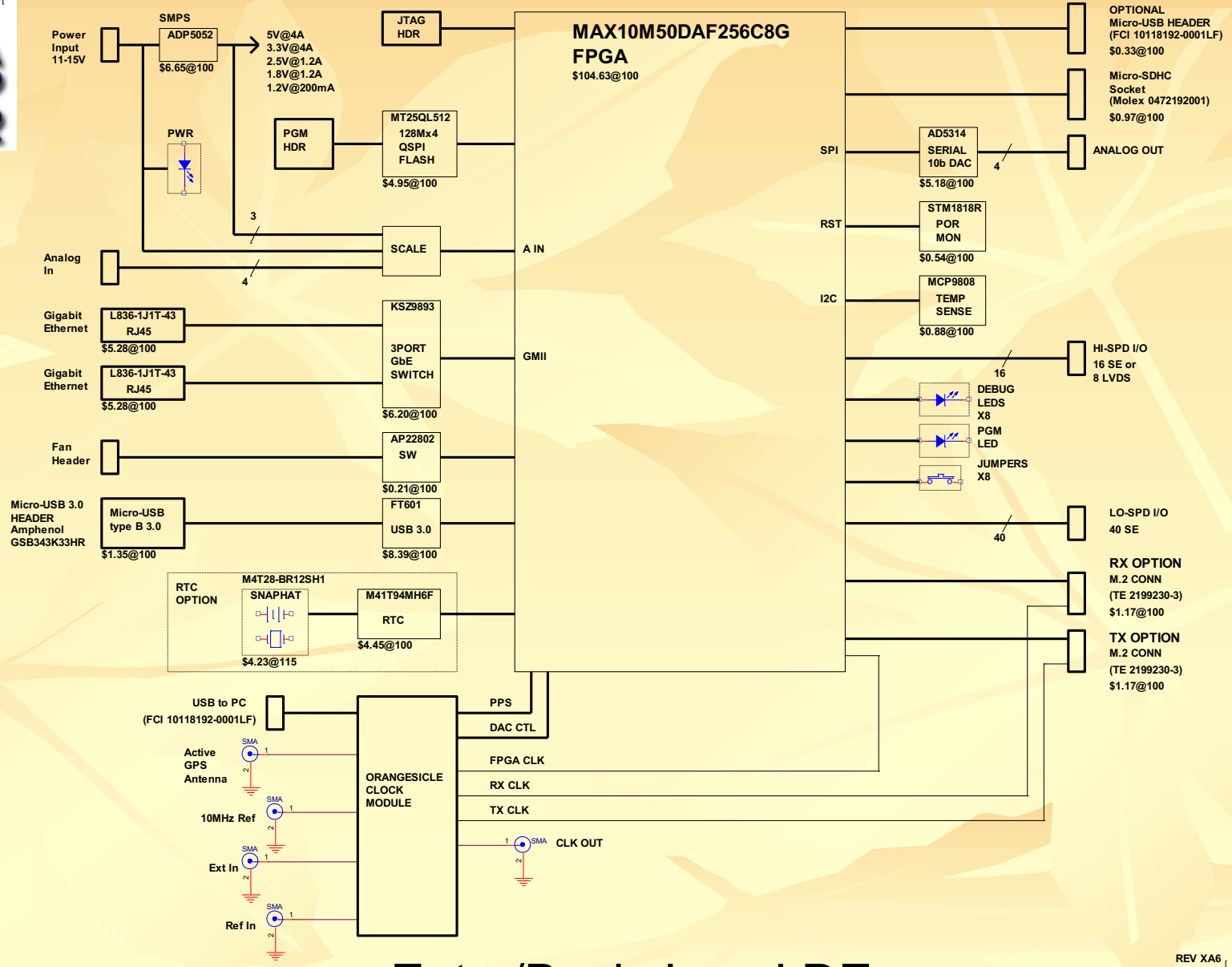
- Two RF module sockets for varying RF price/performance
  - One TX and one RX module ***or***
  - One TRX module
- One oscillator module socket for varying price/performance
  - Commodity grade TCXO, low cost
  - Low jitter, low phase noise VCXO, moderate cost
  - GPSDO, high performance, high cost
- Low speed GPIO for sensor and shield interfaces
- High speed, Single Ended or Differential GPIO

Hardware Features

Basic Level DE Features

All Entry Level features, plus:

- 5Gbps USB 3.0 data interface
- GPS receiver with active antenna and reference inputs
- Extremely low phase noise GPSDO
- Real-time clock with battery backup



Entry/Basic Level DE

Hardware Features

Advanced Level DE Features

All Basic Level features, plus:

- Altera/Intel C5 SoC FPGA, 110K LEs with dual ARM core
- 256MB of DDR SDRAM
- NVMe PCIe X4 SSD port
- Runs Linux networking stack

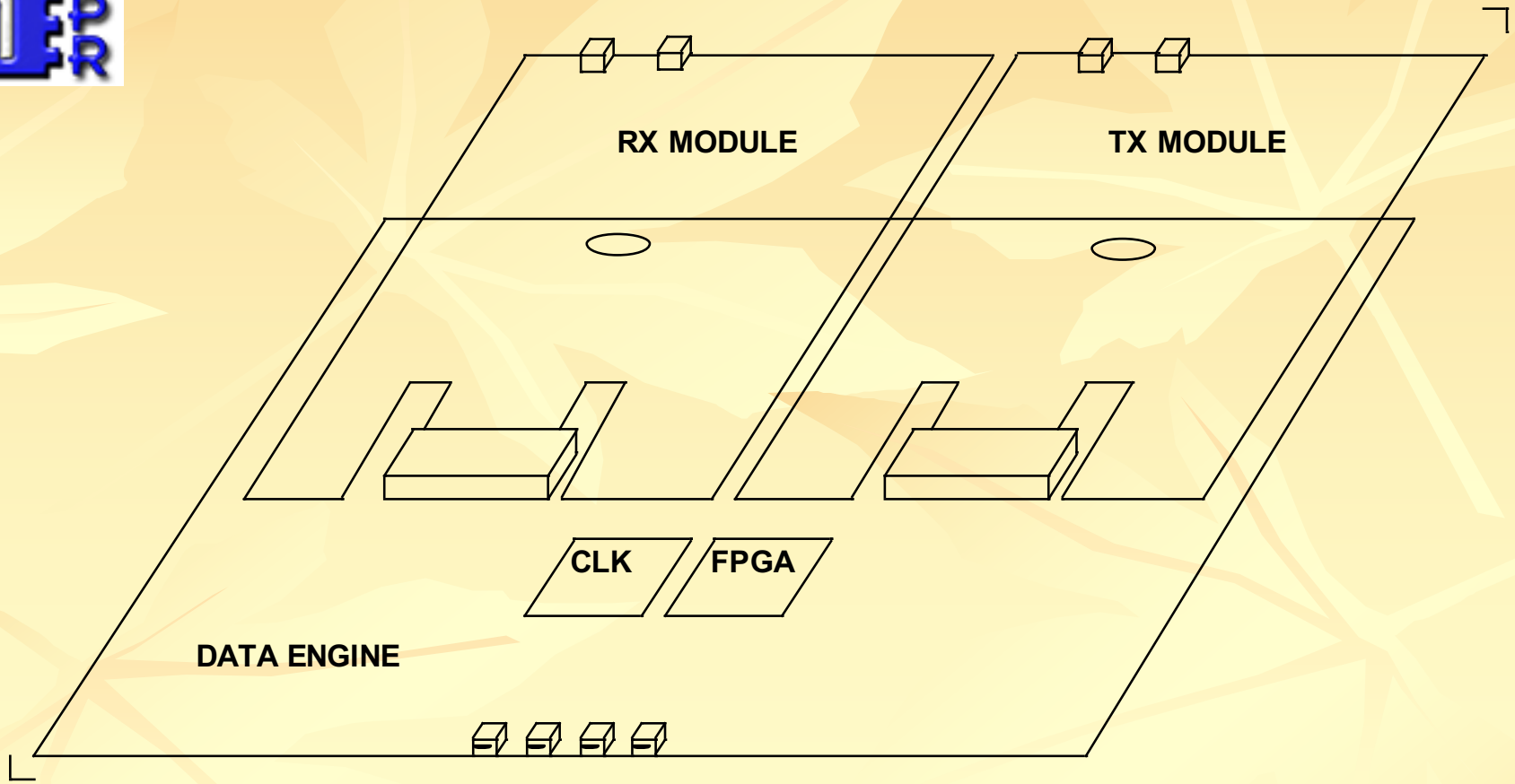
Hardware Features

Future DE Boards

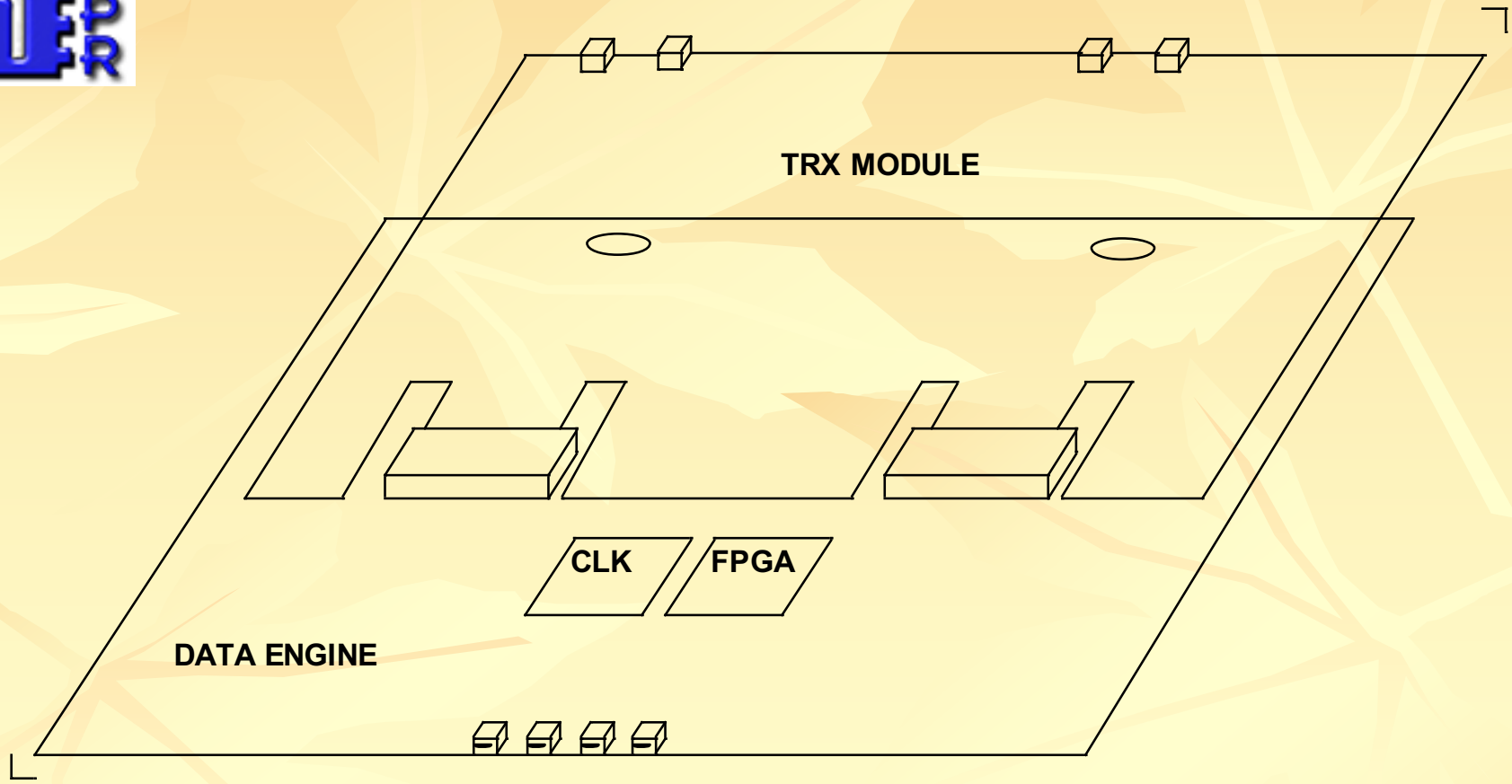
- Larger, faster FPGAs
- More DRAM storage
- More non-volatile (SATA, SSD, etc) storage
- Higher speed data ports (10GE, 40GE, USB 3.2, etc)

BUT…

The same TX/RX module ports allow reuse of RF boards



DE Dual Module Physical Layout

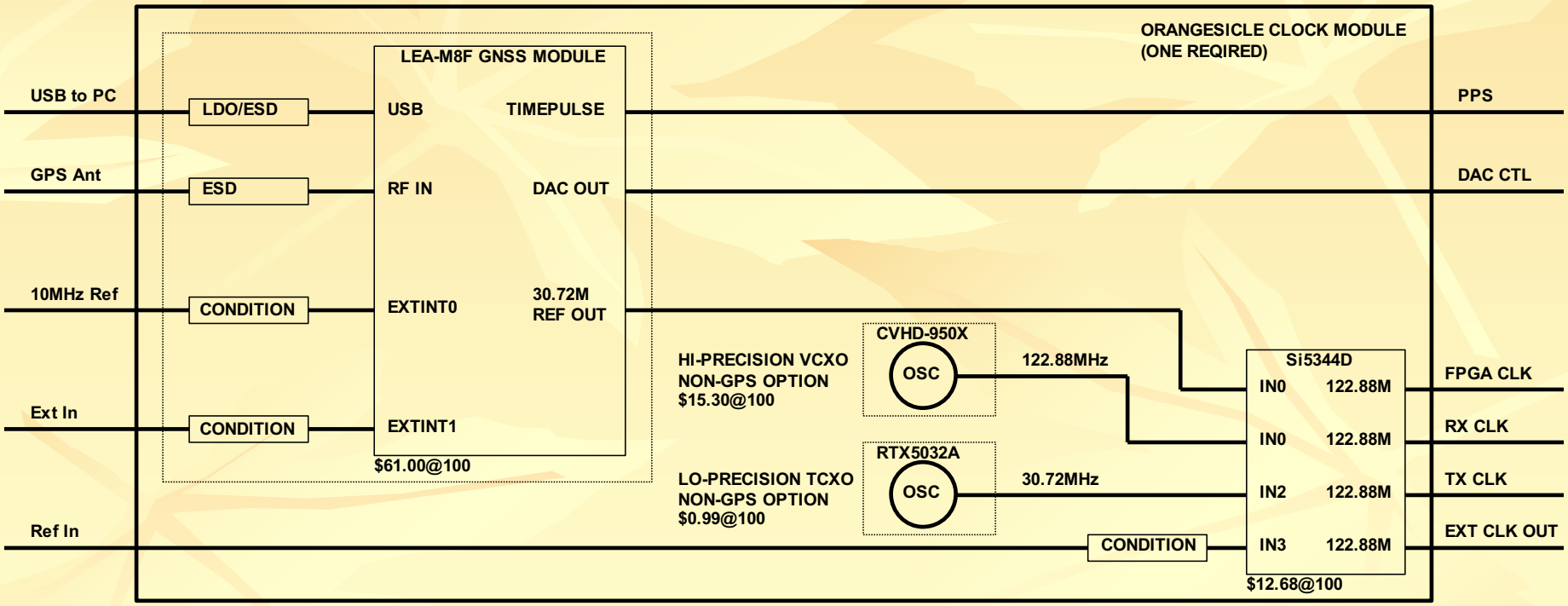


DE Single Module Physical Layout

Hardware Features

Clock Modules

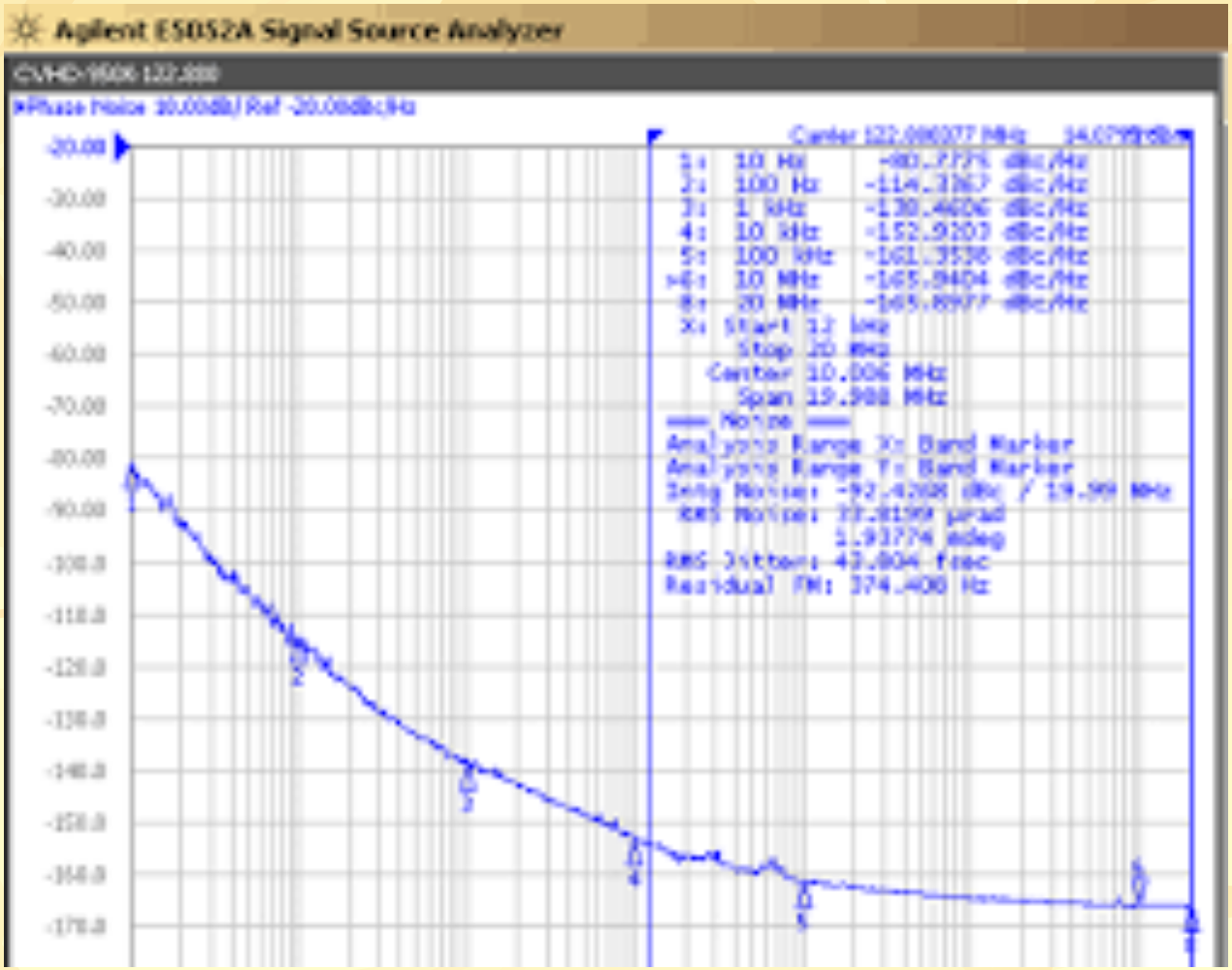
- Basic low-phase noise TXCO (e.g., Rakon RTX5032A)
- High performance VCXO (e.g., Crystek CVHD-950)
- Extreme performance OCXO
- Entry-level GPSDO (LEA-M8F?)
- High-Performance GPSDO (Jackson Labs LTE Lite?)
- Others, as required?



Orangesicle Clock Module

Oscillator Options

CVHD-950 VCXO
Phase Noise



Hardware Features

Orangsicle Shields

- uber (top) Shield
  - Low-speed I/O expander for Sensors
  - May also contain on-board sensors
- unten (bottom) Shield
  - Upper expansion connector mates with Data Engine (DE)
  - Side expansion connectors for one or more side shields
  - Lower expansion connector mates with SBC
- neben (side) Shield
  - Typically contains on-board sensors
  - May provide additional low-speed ports for off-board sensors

Hardware Features

Supported Expansion

- Arduino Shield
- RPi Hat
- Beagle Board Cape
- Click modules
- PMOD (I2C/SPI/UART)
- Ultra96 high-speed expansion port
- Others with additional Orangsicle shields

Hardware Features

RF Modules

- Space Weather Station Receiver (if no TX needed)
- P4G RX and P4G TX modules **or** P4G TRX single module
- AD9361 MIMO transceiver module (70MHz – 6GHz)?
- Lime LMS7002M SDR Module (100kHz – 3.8GHz)?
- Lime LMS8001+ SDR Module (100kHz – 12GHz)?

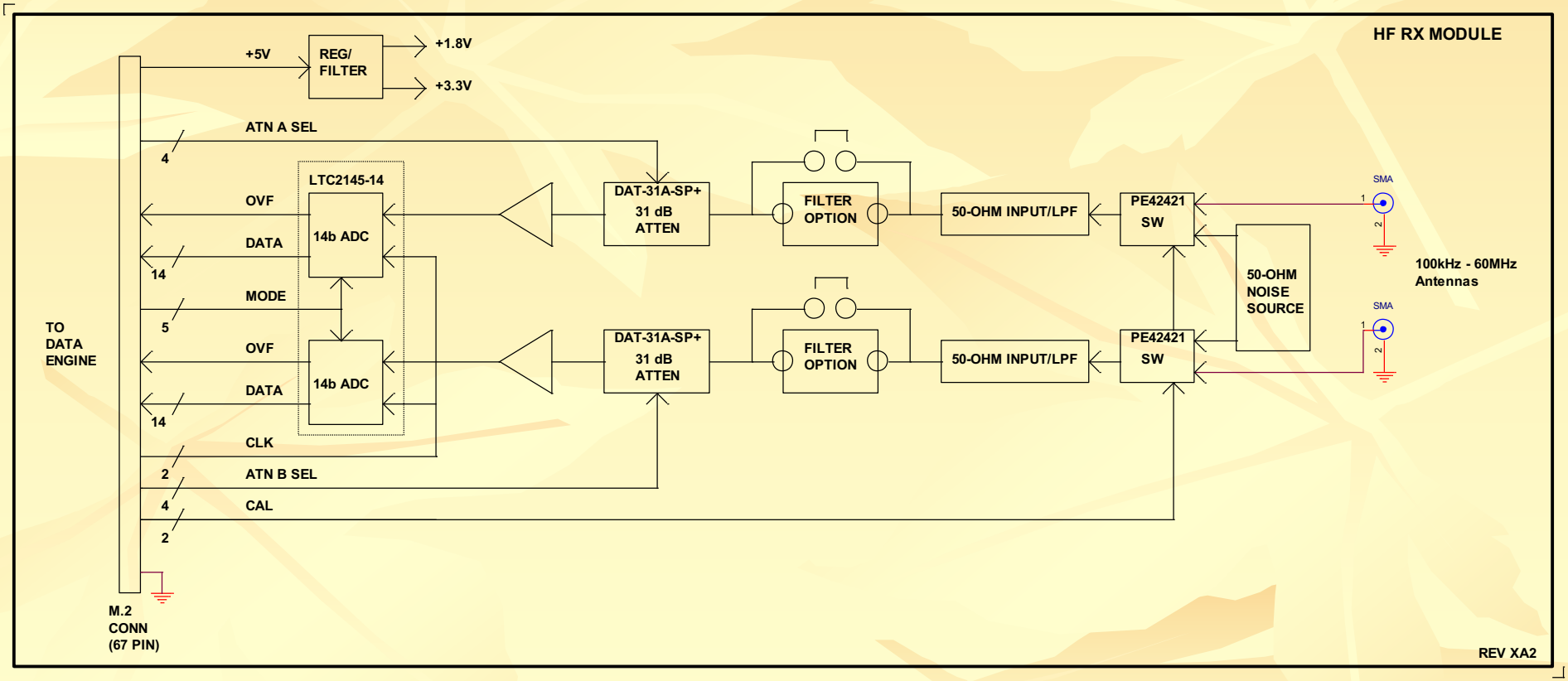
Hardware Features

SWS/HF RX Module

- LTC2145-14 dual 14-bit 122.88Msps ADC
- DAT-31A-SP+ 31-dB step attenuator
- **TBD** LNA
- Fixed 60MHz Low Pass Filter
- Optional user-defined plug-in filter
- On-board, switchable 50-ohm calibration noise source
- On-board low-noise power supplies
- Dual SMA antenna connectors

Hardware Features

SWS/HF RX Module



Thank you!

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