"Flexible Ultrasound System (FUS) for Exploration and Human Research"

Exploration Medical Capability (ExMC) Imaging Integration

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FUS Background

- Exploration Medical Capability (ExMC) owns this HRP risk:
  - *"Risk of Unacceptable Health and Mission Outcomes Due to Limitations of In-flight Medical Capabilities"*
- GRC Imaging Integration Team owns this gap:
  - *ExMC Gap 4.02 "We do not have fully-sufficient non-invasive diagnostic imaging capability and techniques to diagnose conditions on the Space Medicine Exploration Medical Condition List[4]"*

Astronaut André Kuipers images his own eye with Ultrasound-2 on the ISS.

- Flexible ultrasound is an opportunity to help address additional gaps :
  - *ExMC Gap 4.13 Renal stone diagnosis and treatment*
  - *ExMC Gap 4.06 Bone fracture treatment*
  - *HHC Gap Osteo3: Fracture risk assessment due to osteoporosis*
  - *HHC Gap B10: Bone health monitoring*
  - *HHC Gap CV1: Cardiac structure and function monitoring*
  - *HHC Gap VIIP3: Intracranial pressure monitoring, related to the VIIP* syndrome.*
    - ** VIIP = Visual Impairment Intracranial Pressure*

Software-based ultrasound

- Ultrasound will remain NASA's primary "workhorse" modality for internal imaging
- The industry trend toward software-based systems offers numerous advantages to NASA.
  - Greater user flexibility
    - Customized beam forming
    - Targeted receiving and processing techniques
    - Access to the raw ultrasound data set
    - Advanced algorithm development on an ultrasound platform
  - Accommodate novel probe designs
  - Possibly more radiation tolerant design[6]
    - More functionality is implemented in the more generic back-end processor
    - Can leverage flight-qualified processor designs developed for Exploration
    - Easier to meet deep space environments, especially radiation, when there is less custom hardware that is peculiar to the ultrasound system
- The Flexible Ultrasound System (FUS) ground demonstration unit (GDU) development is NASA's effort to begin taking advantage of this new technology.

Flexible Ultrasound System (FUS)

What problems does the project want to solve or address?

1. How can we **improve the clinical diagnostic capability** of Ultrasound-2?

2. How can we **accommodate therapeutic or non-imaging applications** of ultrasound that have been developed by NASA or NSBRI-funded research?

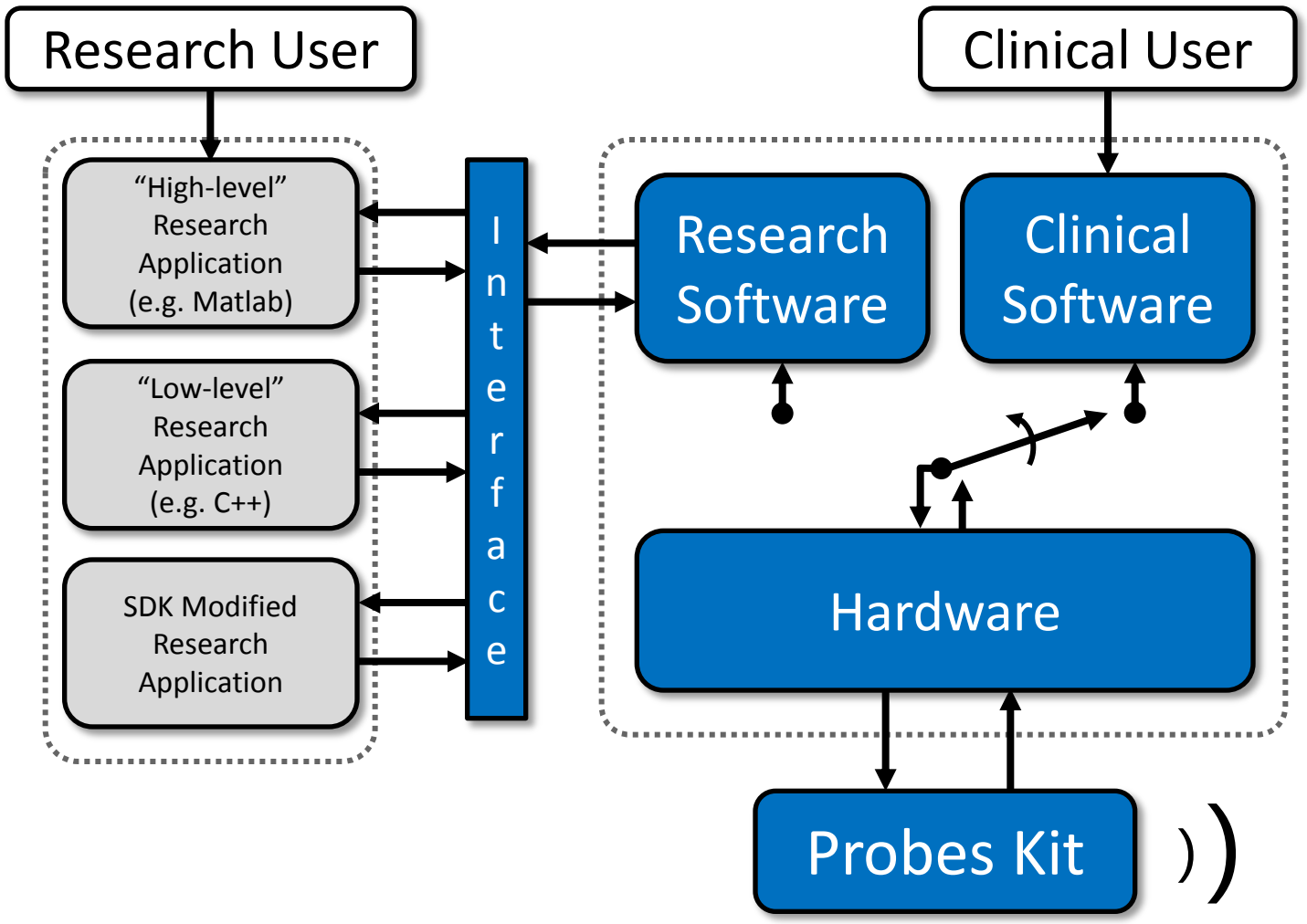
3. How can we confidently design an ultrasound unit to **survive the high ionizing radiation levels** of low-earth orbit and (especially) deep space?

4. How can we **enable ultrasound to communicate with other devices** as part of an integrated medical system (e.g., EMSD) that a minimally trained crew can operate?

2012 Accomplishments/Current Status

- The Imaging Integration team at GRC recently initiated a successful procurement effort via an RFP to develop a Flexible Ultrasound System (FUS) ground demonstration unit (GDU).
  - ConOps and System Requirements Document (SRD) approved by ExMC Advisory Board in early 2012
  - Market survey and two sources sought solicitations (SSS) preceded the RFP release
  - Three companies expressed interest in the SSS's
    - GE Global Research Center
    - Verasonics
    - Ultrasonix
  - The first two vendors submitted proposals to the Statement of Work (SOW) in the RFP.
  - GE Global Research Center was selected in Autumn 2012
  - Contract award: Final signatures on February 4, 2013
  - All requirements should be met by the FUS design

FUS Ground Demo Unit Overview



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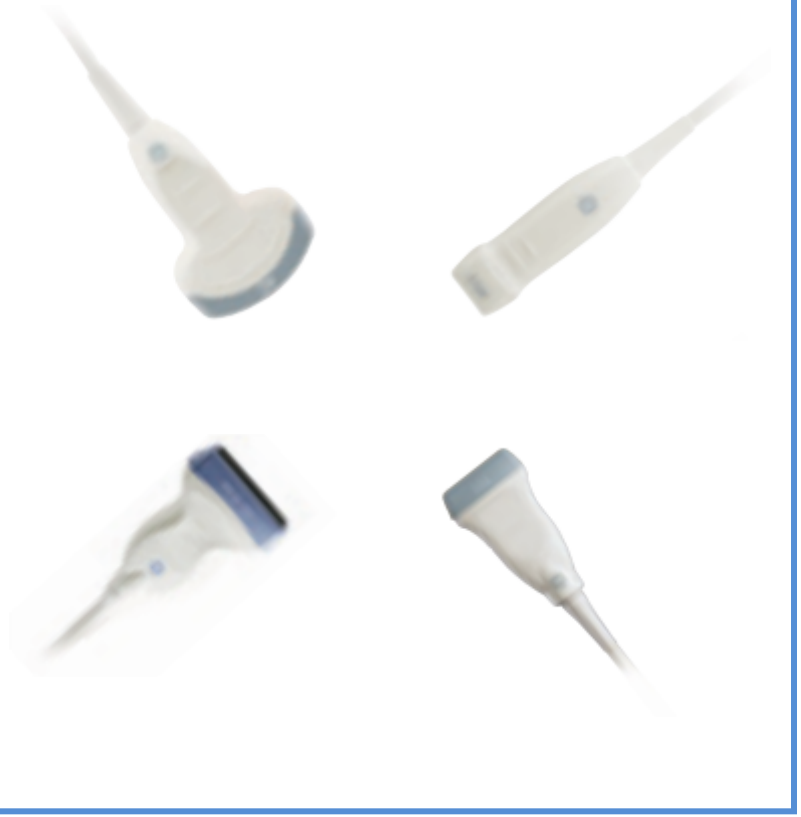
FUS Ground Demo Unit Capabilities

Hardware
- >= 12 bit Rx data
- >= 0.2-15MHz Rx Center Freq
- >= 128 Tx & Rx channels
- >= 40MSps Rx data
- Programmable Anti-aliasing filters

Research Probes
- M5S-D (1.5-4.5MHz Phased)
- 4C-D (1.6-6MHz Convex)
- 11L-D (3-11MHz Linear)
- ML6-15-D (4.5-15MHz Multi-row Linear)
- Custom probe support

Other
- Channel data
- Controllable transmit power
- Trigger control

Software
- Traditional Clinical Mode
- Research Mode
- SDK



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FUS Advanced Research Capabilities

- **High Power Transmit Module**
- Provides additional transmit power (>= 10W Acoustic Power) for high power tasks
- High Duty Cycle (up to 50%) operations
- Feedback power protections
- Augmented thermal performance
- Authenticated operation

- **Dual Probe Interface**
- Allow for multiple simultaneous probe connections
- Half total channels available for transmit and receive on each probe
- Multi-channel or single channel
- Support for probe configuration

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Research Mode Use Model

How PI teams can develop applications on the Research Interface

- Language Agnostic Interface
  - Abstracted configuration
  - Use the language of your choice

  (C++ and Matlab supported by SDK)
- Familiar Windows development environment
- Programmable Hardware Control:
- Transmit Delays, Transmit Waveform, Scan Sequence, TGC, Filters, more

- Hardware independent operation
  - Develop on a desktop independent of hardware (simulator mode)
- Software Development Kit
  - Provided SDK expandable designs
  - Design quick-start
  - Example usage and implementation
- Development Support
  - Manuals, Guides, Code Comments, and Technical Assistance

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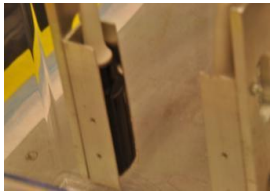
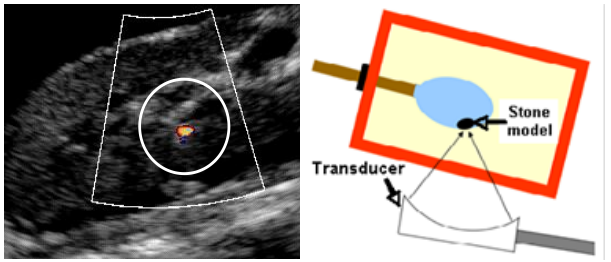
Forward Work – Integration of PI Applications with FUS

- Targeted ultrasound investigators
  - Quantitative Ultrasound (QUS) for bone health monitoring[1] *[SUNY Stony Brook]*
  - Low intensity pulsed ultrasound (LIPUS) for fracture healing[2] *[SUNY Stony Brook]*
  - Wideband Single-crystal QUS probe[5] *[TRS Technologies]*
  - Acoustic renal stone manipulation[3] *[U of WA]*
  - Volumetric ophthalmic imaging to monitor intra-cranial pressure[7] *[GE-GRC]*
  - Other NASA or NSBRI-funded researchers who can take advantage of the FUS capabilities
- These techniques require
  - Support of novel probes (multiple probes)
  - Full control of beam-forming and power
  - Full access to the raw ultrasound data
  - High frequency range of operation (0.2 – 15.0 MHz)
- With the contract now signed, we are ready to begin!

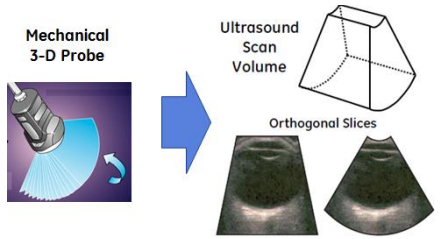


QUS 2-probe configuration[1]

Wideband QUS probe[5]

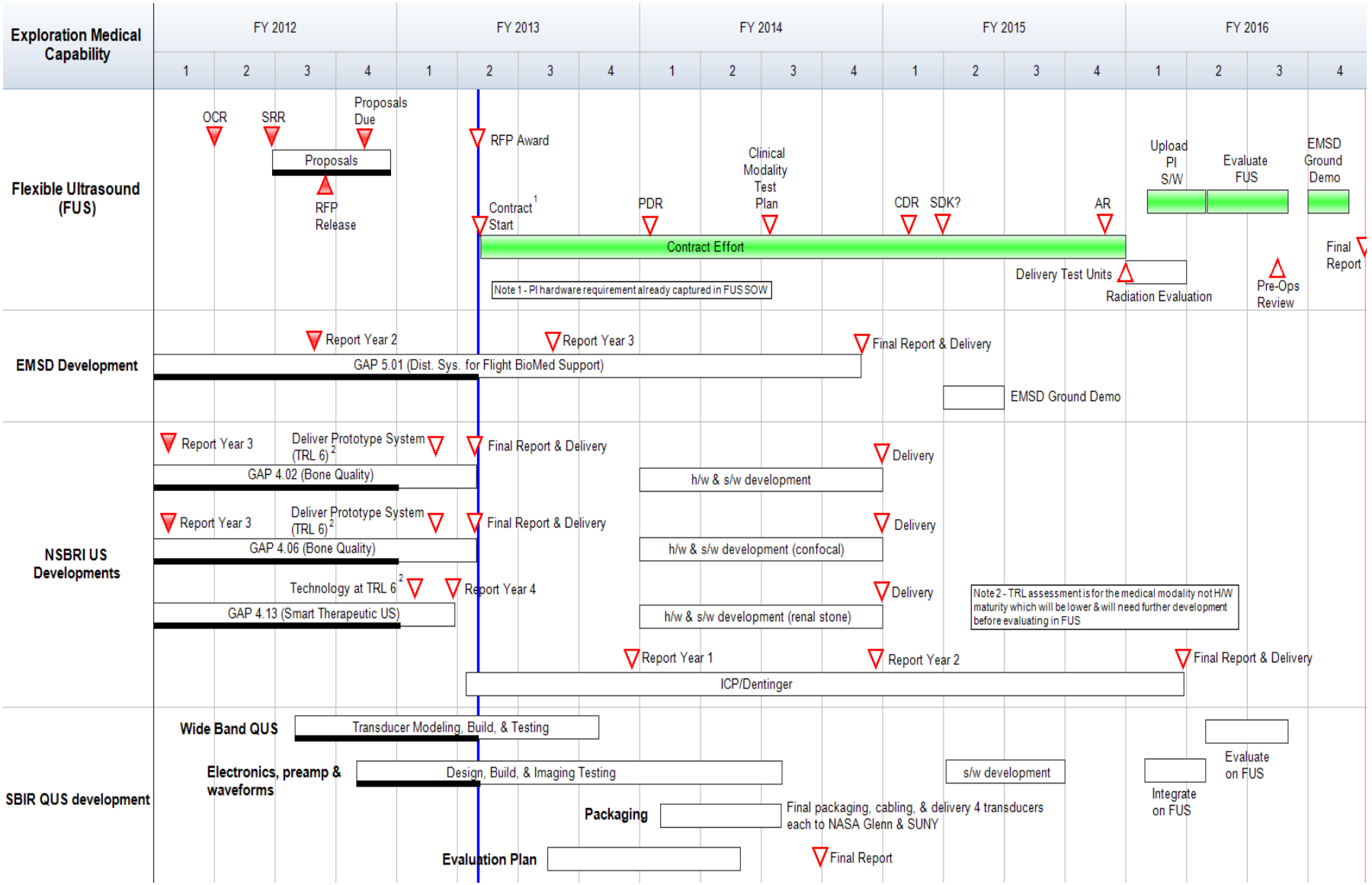


Renal stone detection/manipulation[3]



Ophthalmic 3DUS for ICP monitoring

Integration of Research Modalities on to FUS Platform



Summary of Key Points

- Expand the diagnostic capability of Ultrasound-2

- Advance the TRL of NASA and NSBRI-funded research utilizing ultrasound by providing an integrated development platform.
    - *Therapeutic modes*
    - *Non-imaging modes*

- First stepping stone toward eventually meeting deep space radiation environments on long-duration missions.

- Ground-based demonstration in 2015 with EMSD.

- Possible EMSD flight demonstration in 2016 or beyond (not yet funded).

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Questions?

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