UWB Technology and Applications on Space Exploration

Abstract

Ultra-wideband (UWB), also known as impulse or carrier-free radio technology, is one promising new technology. In February 2002, the Federal Communications Commission (FCC) approved the deployment of this technology. It is increasingly recognized that UWB technology holds great potential to provide significant benefits in many terrestrial and space applications such as precise positioning/tracking and high data rate mobile wireless communications.

This talk presents an introduction to UWB technology and some applications on space exploration. UWB is characterized by several uniquely attractive features, such as low impact on other RF systems due to its extremely low power spectral densities, immunity to interference from narrow band RF systems due to its ultra-wide bandwidth, multipath immunity to fading due to ample multipath diversity, capable of precise positioning due to fine time resolution, capable of high data rate multi-channel performance. The related FCC regulations, IEEE standardization efforts and industry activities also will be addressed in this talk. For space applications, some projects currently under development at NASA Johnson Space Center will be introduced. These include the UWB integrated communication and tracking system for Lunar/Mars rover and astronauts, UWB-RFID ISS inventory tracking, and UWB-TDOA close-in high resolution tracking for potential applications on robonaut.

UWB Technology and Applications on Space Exploration

Dickey Arndt

Phong Ngo, Chau Phan, Julia Gross, John Dusl, Jianjun (David) Ni

UWB Systems Group / EV4

Avionic Systems Division / EV

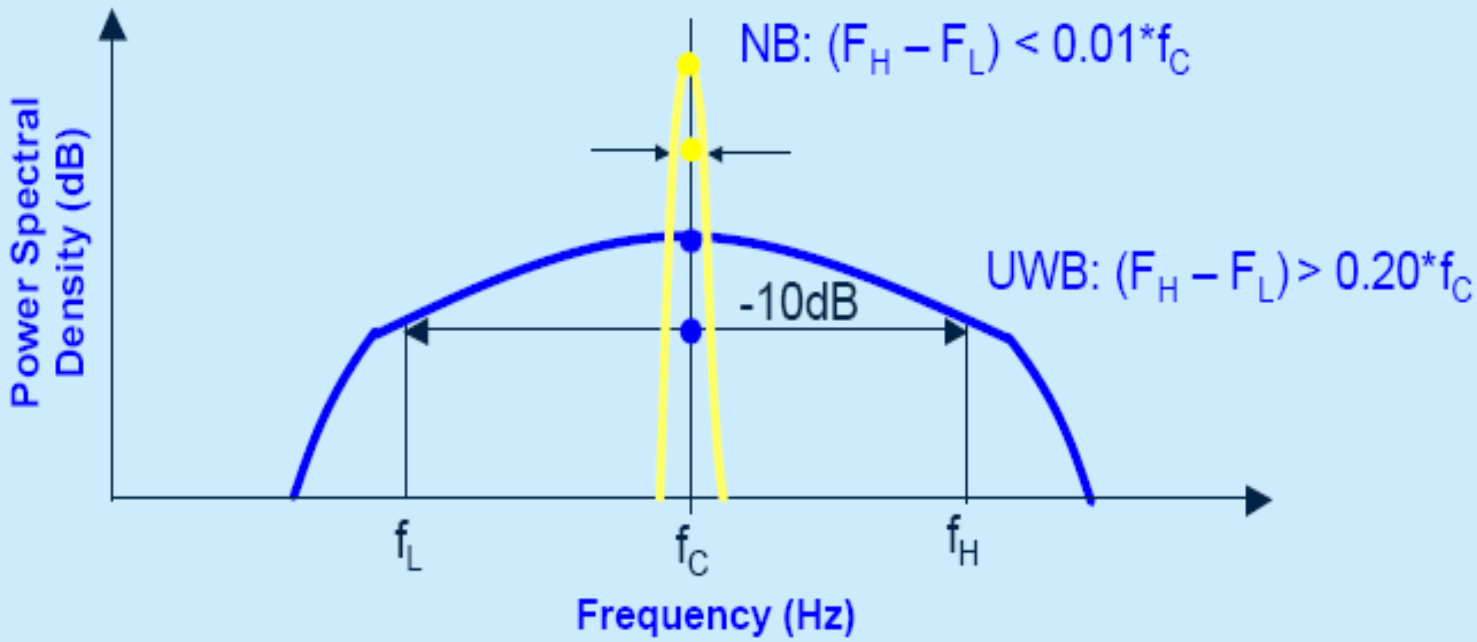
NASA Johnson Space Center

Outline

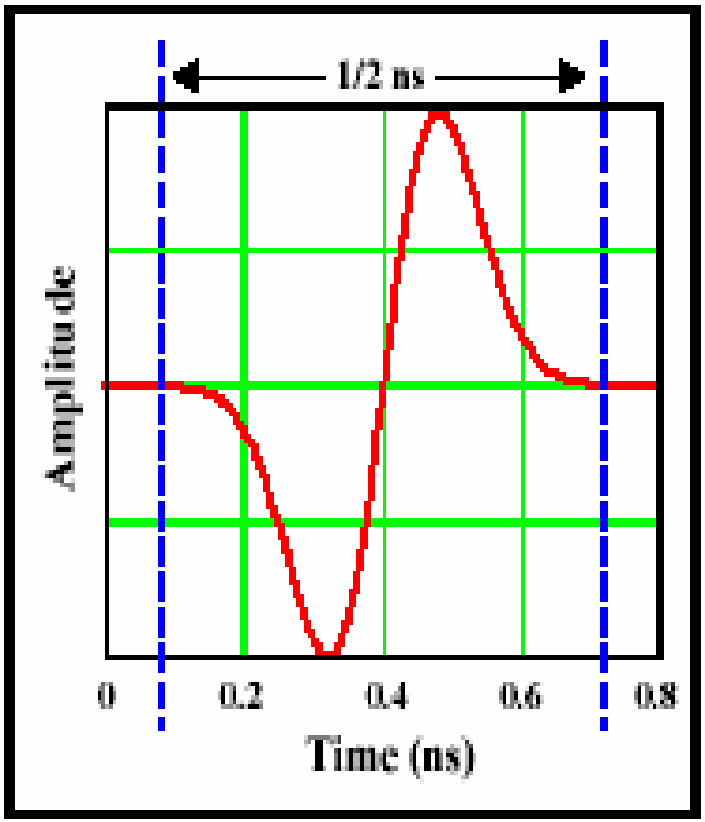
- Introduction to UWB Technology
- FCC Regulations
- IEEE Standardization Efforts
- UWB Applications
- Development at NASA/JSC

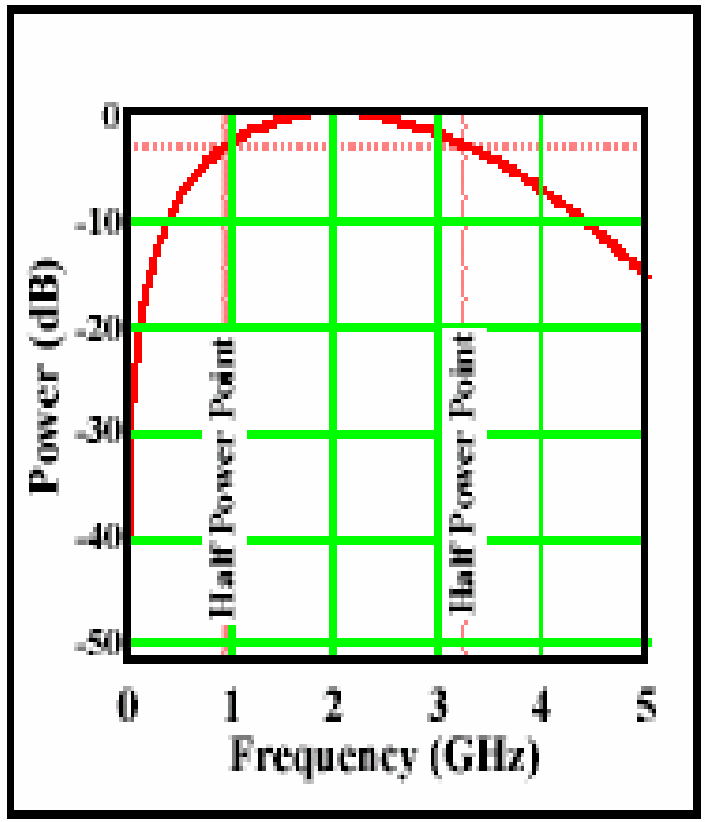
What is UWB ? (FCC Definition)

A ultra wideband device is defined as any device where the fractional bandwidth is greater than 0.20 or occupies 500 MHz or more of spectrum.



UWB Pulse in Time and Frequency Domain





Why UWB?

- The motivation for UWB can be understood by looking at the capacity equation for a Gaussian channel. More "bang-for-the-buck" by increasing bandwidth, than increasing power.

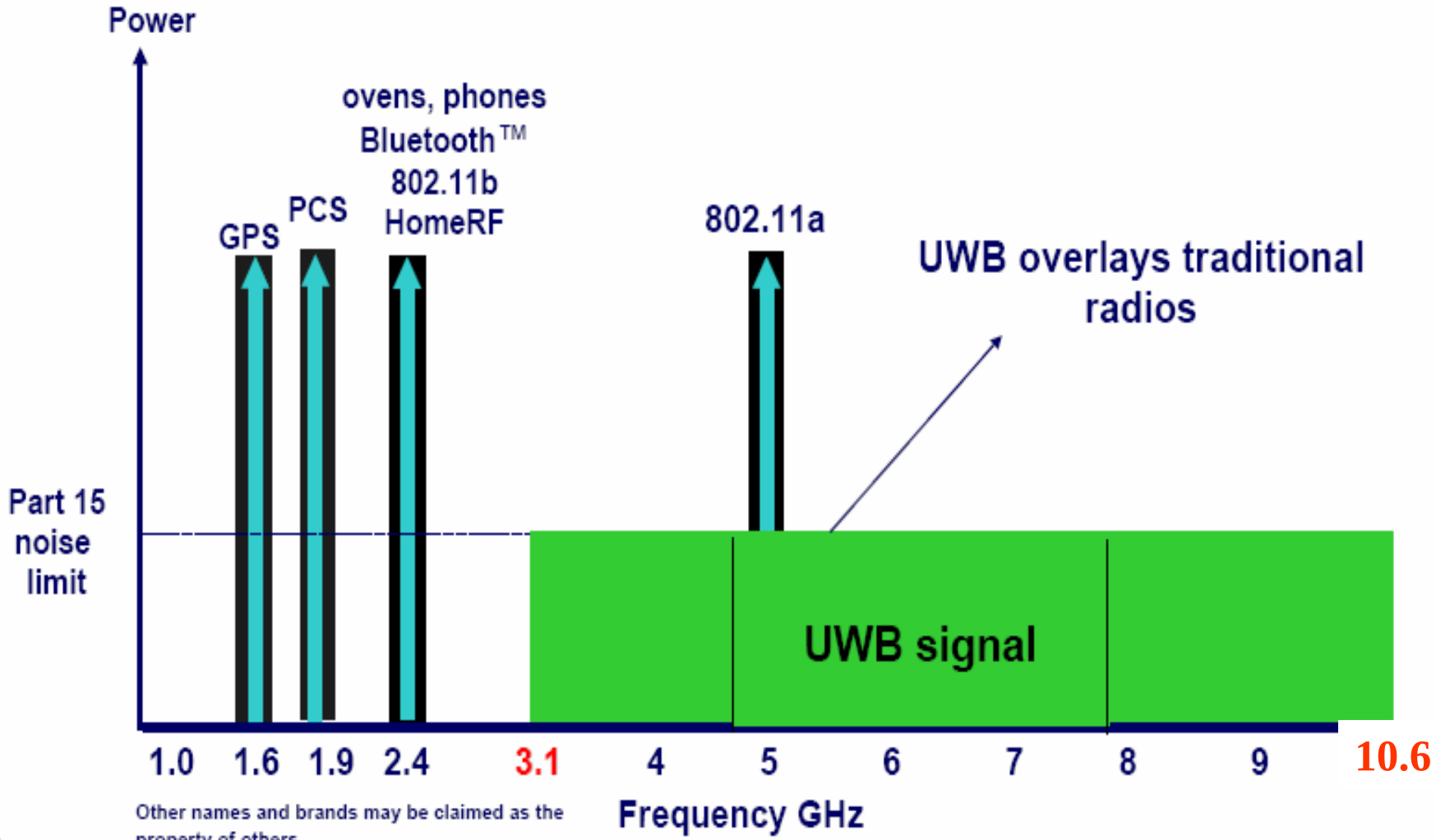
Capacity of a Gaussian Channel:

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

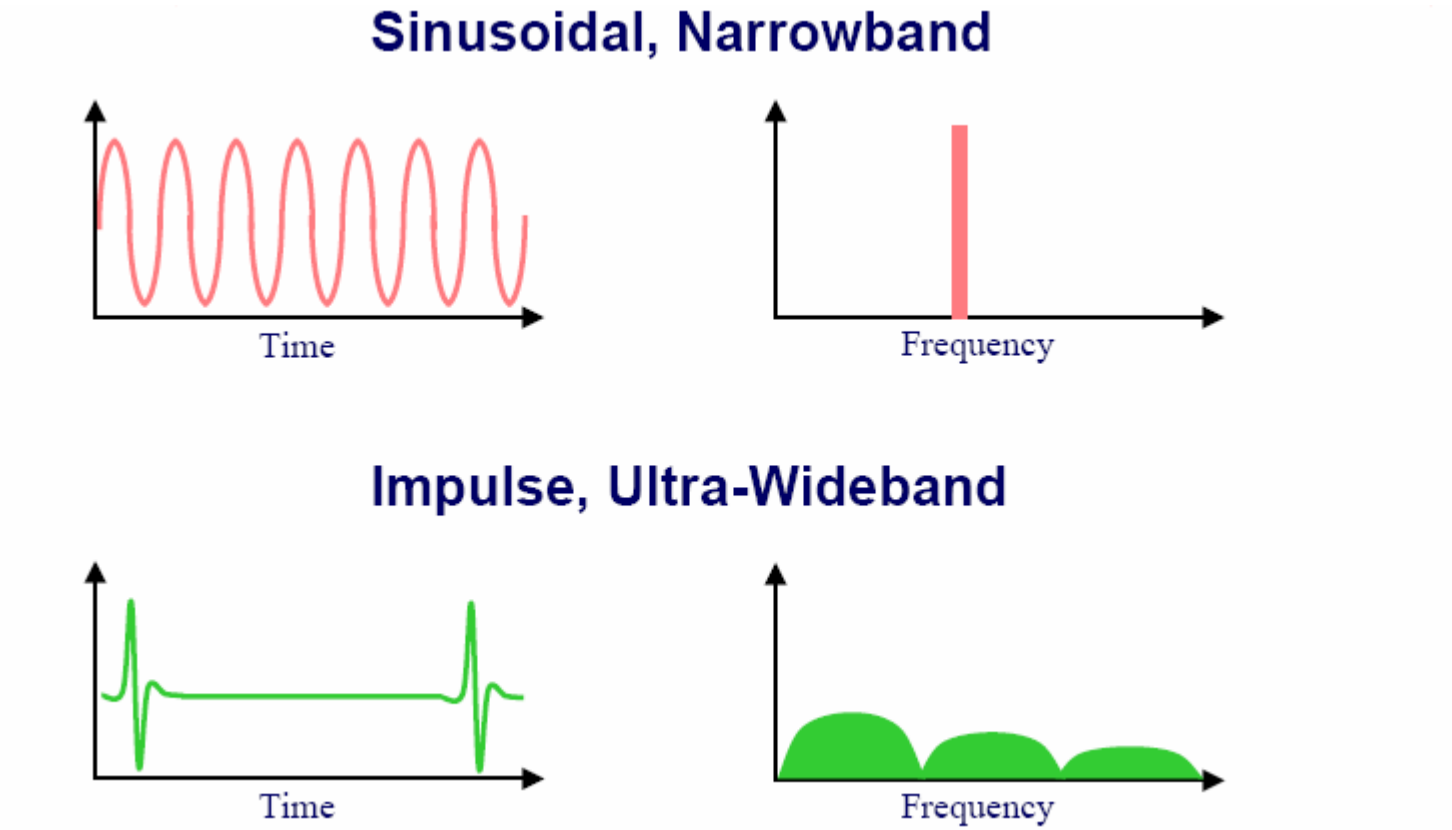
Where:
C = Maximum Channel Capacity (bits/sec)
B = Channel Bandwidth (Hz)
S = Signal Power (watts)
N = Noise Power (watts)

**C grows linearly with B,
but only logarithmically with S/N**

UWB vs. Current Radios

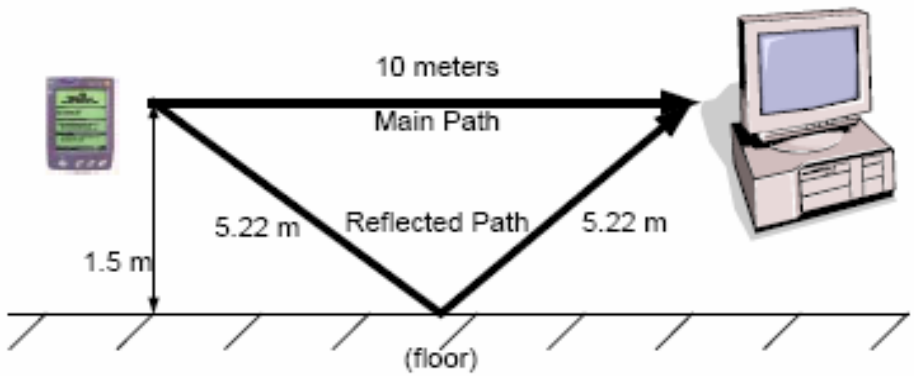


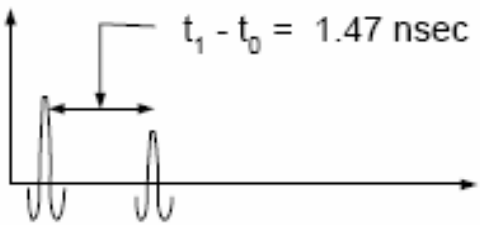
UWB Fine Time Resolution



Multipath Resistance

- Short impulse (< 1 nsec typically) prevents destructive interference
- Multipath components can be individually resolved
- Carrier-less nature of waveform results in less fading, even when pulses overlap

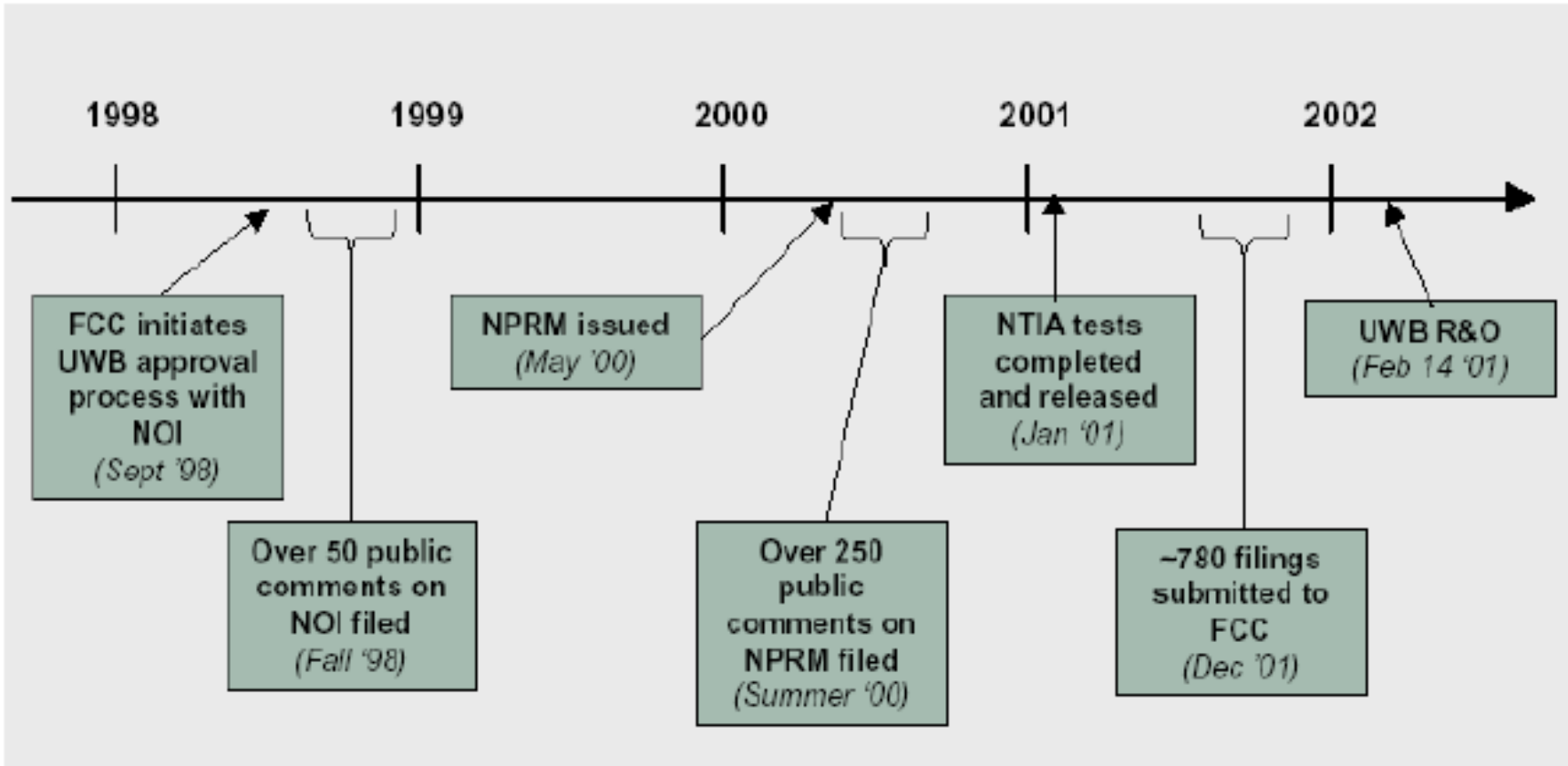




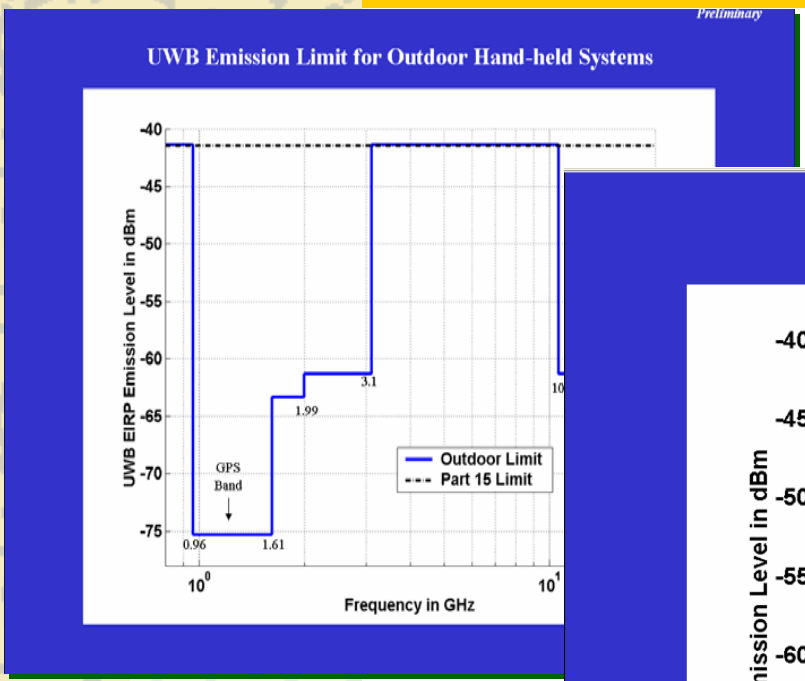
Advantages of UWB

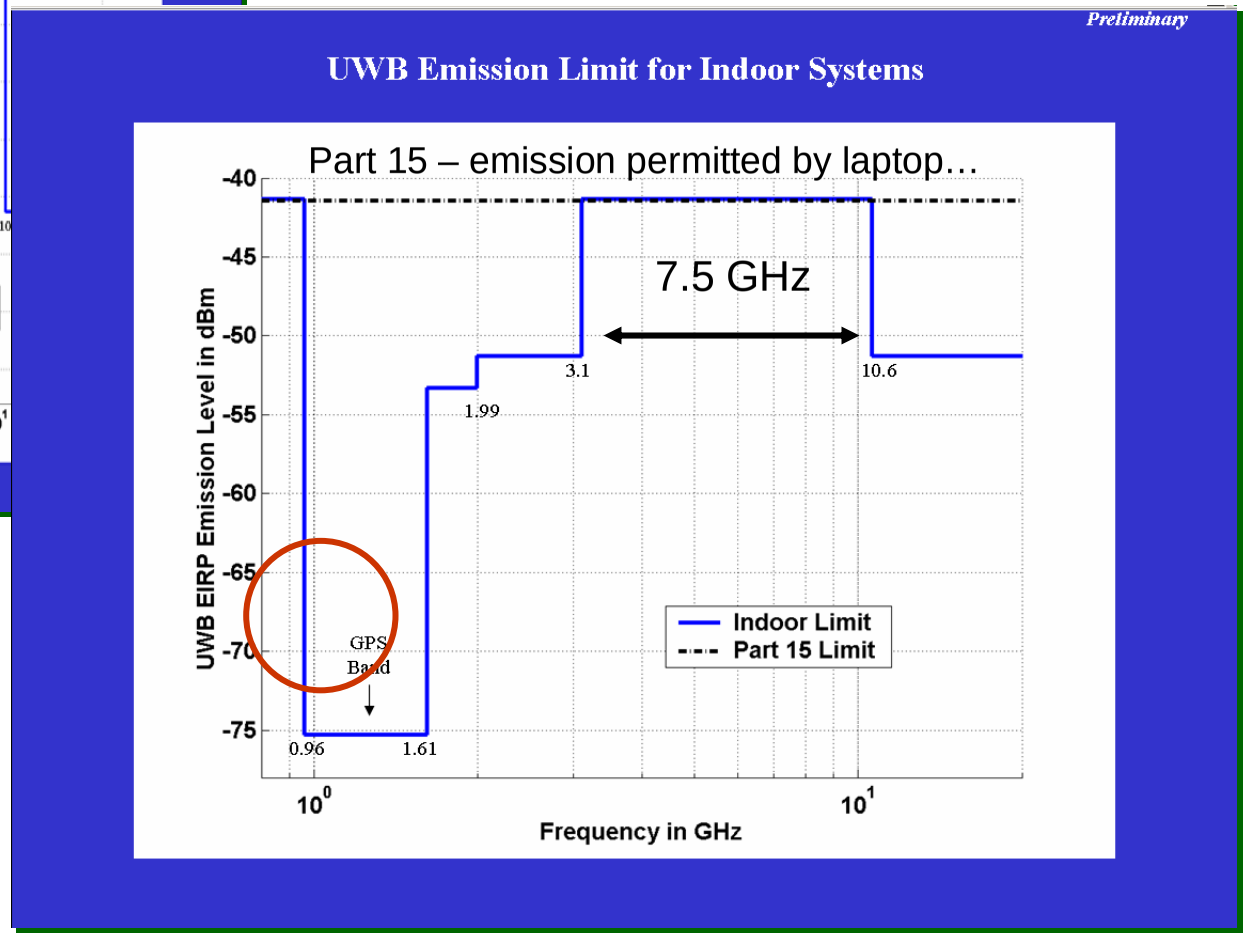
- Robustness to multipath fading: Suitable for high-speed, mobile wireless communications
- Spectrum efficiency: High bandwidth and data rate, coexisting with existing services
- Low transmitted power/power density
- LPI/LPD: Low probability of intercept/detection, ideal for military applications
- Multi-channel: Potentially many users can coexist with little mutual interference

FCC - Regulatory Process



FCC Mask: Defining “UWB”





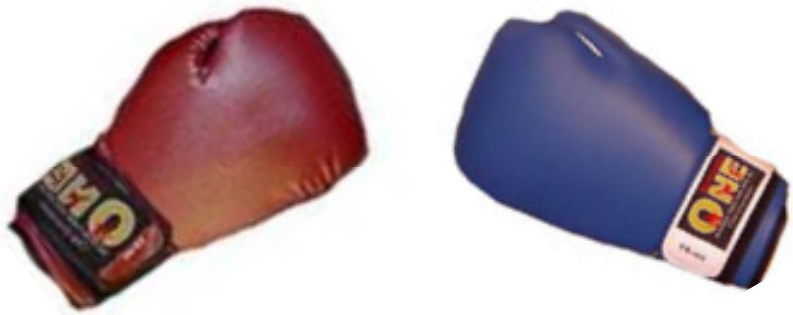
UWB Standardization

freescale semiconductor

Cable-Free USB

UWB Forum

Direct Sequence UWB



Wireless USB

WiMedia Alliance

Multi-band OFDM

PulseLINK

SAMSUNG ELECTRONICS

BELKIN

intel

SAMSUNG ELECTRONICS

PHILIPS

NOKIA

Microsoft

SONY

FUJITSU

Texas Instruments

TDK

STACCATO COMMUNICATIONS

MAXIM

Logitech

NEC

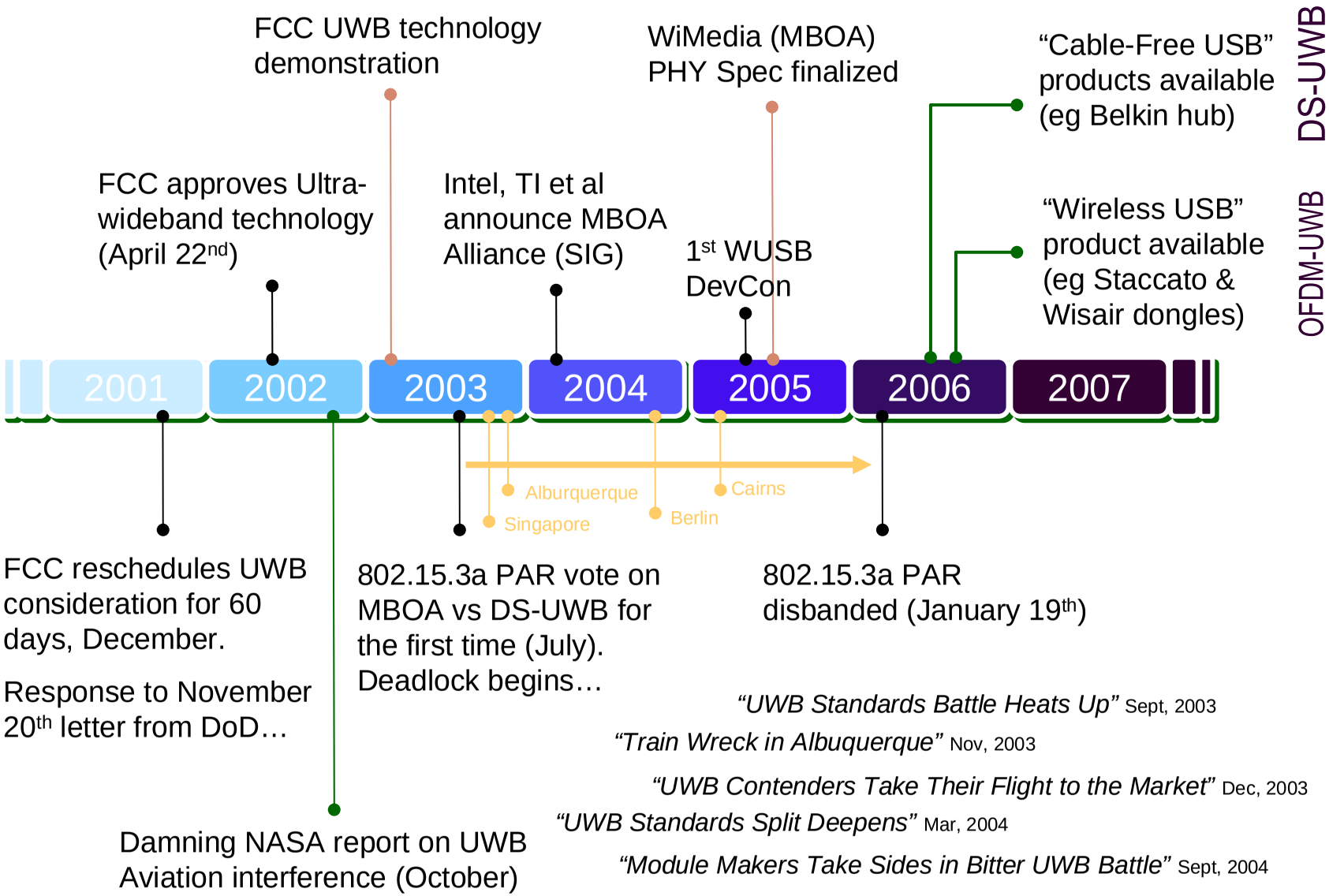
NEC Electronics

MITSUBISHI ELECTRIC

Panasonic

BROADCOM

The Blue Period: IEEE 802.15.3a



"UWB Standards Battle Heats Up" Sept, 2003

"Train Wreck in Albuquerque" Nov, 2003

"UWB Contenders Take Their Flight to the Market" Dec, 2003

"UWB Standards Split Deepens" Mar, 2004

"Module Makers Take Sides in Bitter UWB Battle" Sept, 2004

Applications of UWB (1/3)

- **Communications**: High-speed (~100 Mb/s) and high-performance wireless networks
  - High-speed wireless networks (home, office, schools, telemedicine)
  - Wireless broadband internet access (ultra low power, anywhere, anytime, all the time)
  - Private radio
  - Indoor broadband cellular phone
  - Military applications (tactical handheld & network LPI/D radios, non-LOS LPI/D groundwave communications)

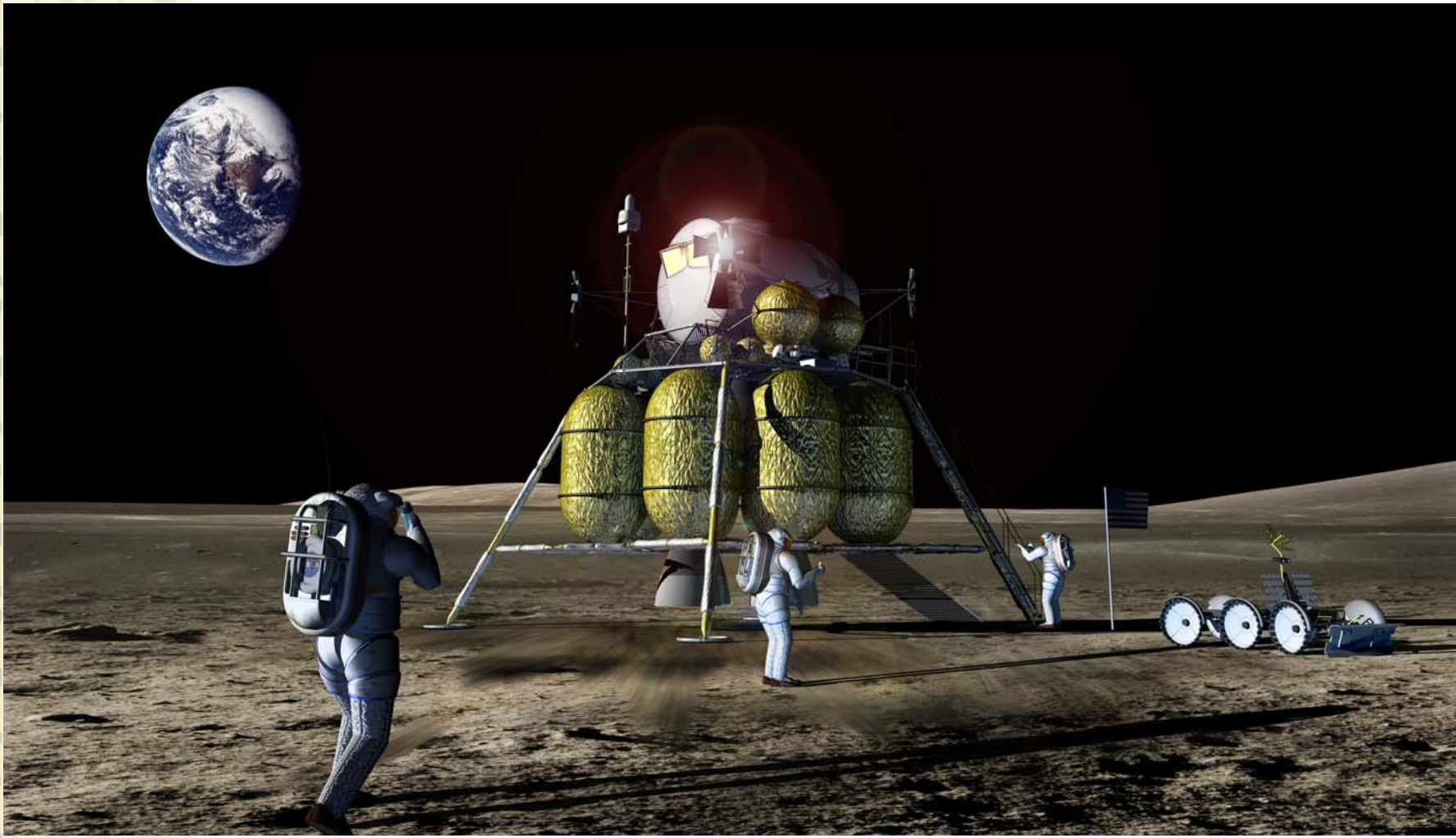
Applications of UWB (2/3)

- **Radar**: High-resolution radar systems
  - Through-wall imaging and motion sensing radar
  - Security systems for alarming and tracking movement
  - Underground imaging
  - Automotive collision-avoidance sensors
  - Precision measurement devices
  - Robotic sensors
  - Aviation safety improvements
  - Military applications (intrusion detection radars, proximity fuzes, unmanned ground and aerial vehicles)

Applications of UWB (3/3)

- **Tracking**: Ultra-precise positioning systems for seamless indoor and outdoor tracking
  - People tracking (tags, smart appliances)
  - Asset tracking
  - In-building tracking
  - Aviation ground tracking
  - Ultra precise positioning systems (precision navigation, precision farming)
  - Military applications (facility and personnel security, logistics)

UWB for Space Exploration



UWB Development at NASA/JSC

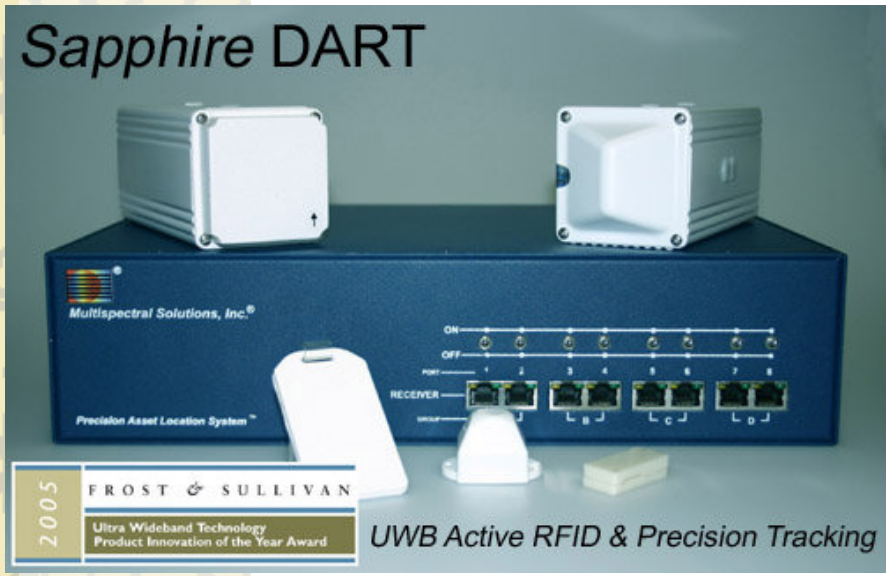
- UWB Two-Cluster AOA Tracking Prototype System
  - Excellent tracking performance with less than 1% error at ranges up to 3500 ft
  - No RF interference with on-board GPS, video, audio, and telemetry systems

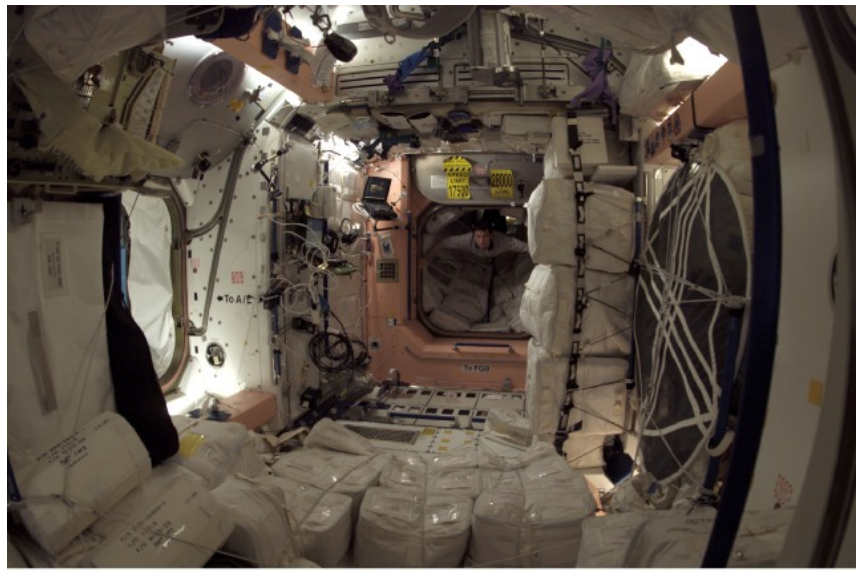
UWB Development at NASA/JSC

- UWB-RFID for ISS Inventory Tracking

* Evaluate UWB-RFID system Sapphire DART

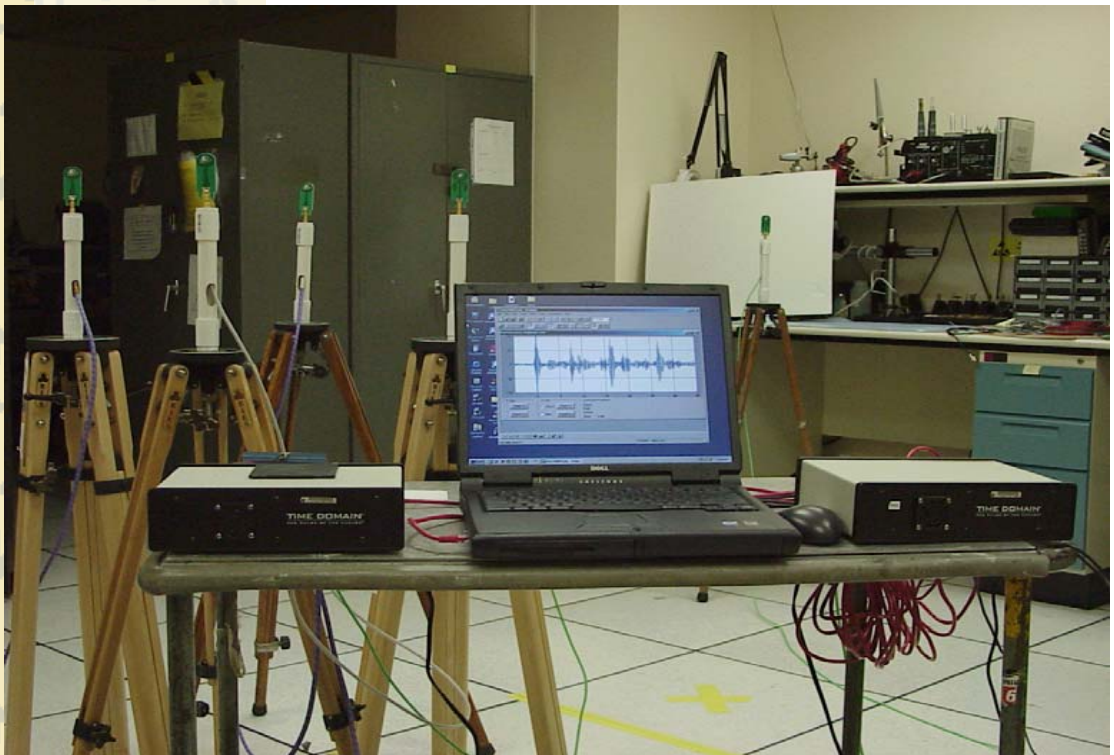
* Customize the system and enhance the tracking algorithm performance





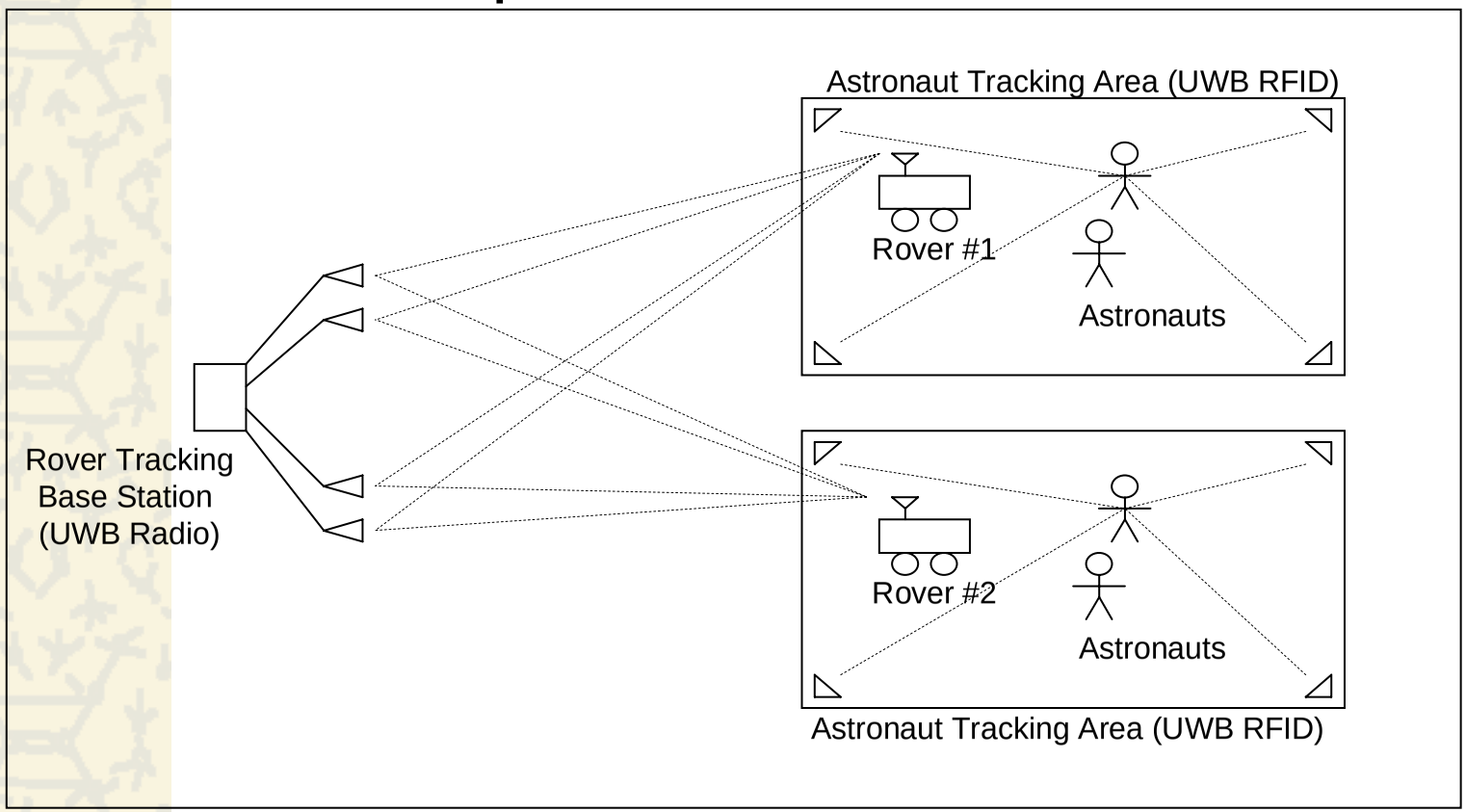
UWB Development at NASA/JSC

- UWB TDOA High Resolution Proximity Tracking for Robonaut
- Theoretical analysis and simulation for TDOA proximity applications
- Lab tests show sub-inch tracking resolution



UWB Development at NASA/JSC

- Integrated UWB Communication and Tracking System for Lunar Surface Exploration



UWB Systems Group
(A Functional Team Architecture)