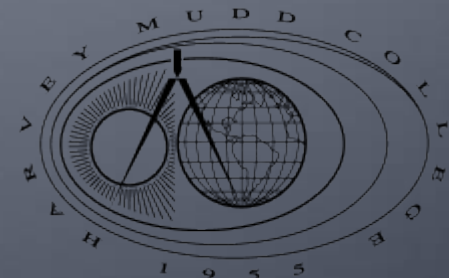


Spaceborne Emergency Distress Beacon

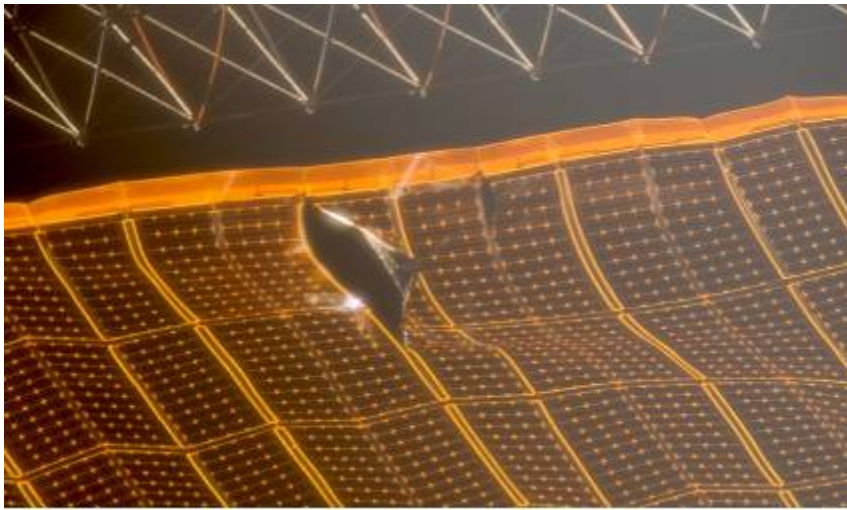
Andrew Danowitz (Harvey Mudd College),
Nathaniel Pinckney (Harvey Mudd College),
Michael Braly (Harvey Mudd College),
Howard Chen (Harvey Mudd College),
Andrew Giles (Harvey Mudd College),
Sarah L. Harris, Ph.D. (Harvey Mudd College),
Samuel S. Osofsky, Ph.D. (The Aerospace Corporation)



Background

- 2007 extra-vehicular activities (EVAs) up 64% from 2006, 229% from 2005
- Space tourism likely to increase number of EVAs
- Potential dangers :
 - Broken tethers
 - Medical emergencies

EVA Hazards



- Recent EVAs contain significant danger
 - Solar panels were operational during repair

Image: Photo Courtesy of NASA

Current Emergency Detection

- Astronauts monitored by mission control
- Spacesuit radio
 - Communicates medical sensor readings
 - Transmits voice communications
- Potential dangers
 - Equipment malfunction
 - RF interference
 - Unknown astronaut location

Optical distress beacons provide a redundant means for locating astronauts in distress



Photo Courtesy of NASA



Photo Courtesy of NASA



Photo Courtesy of NASA

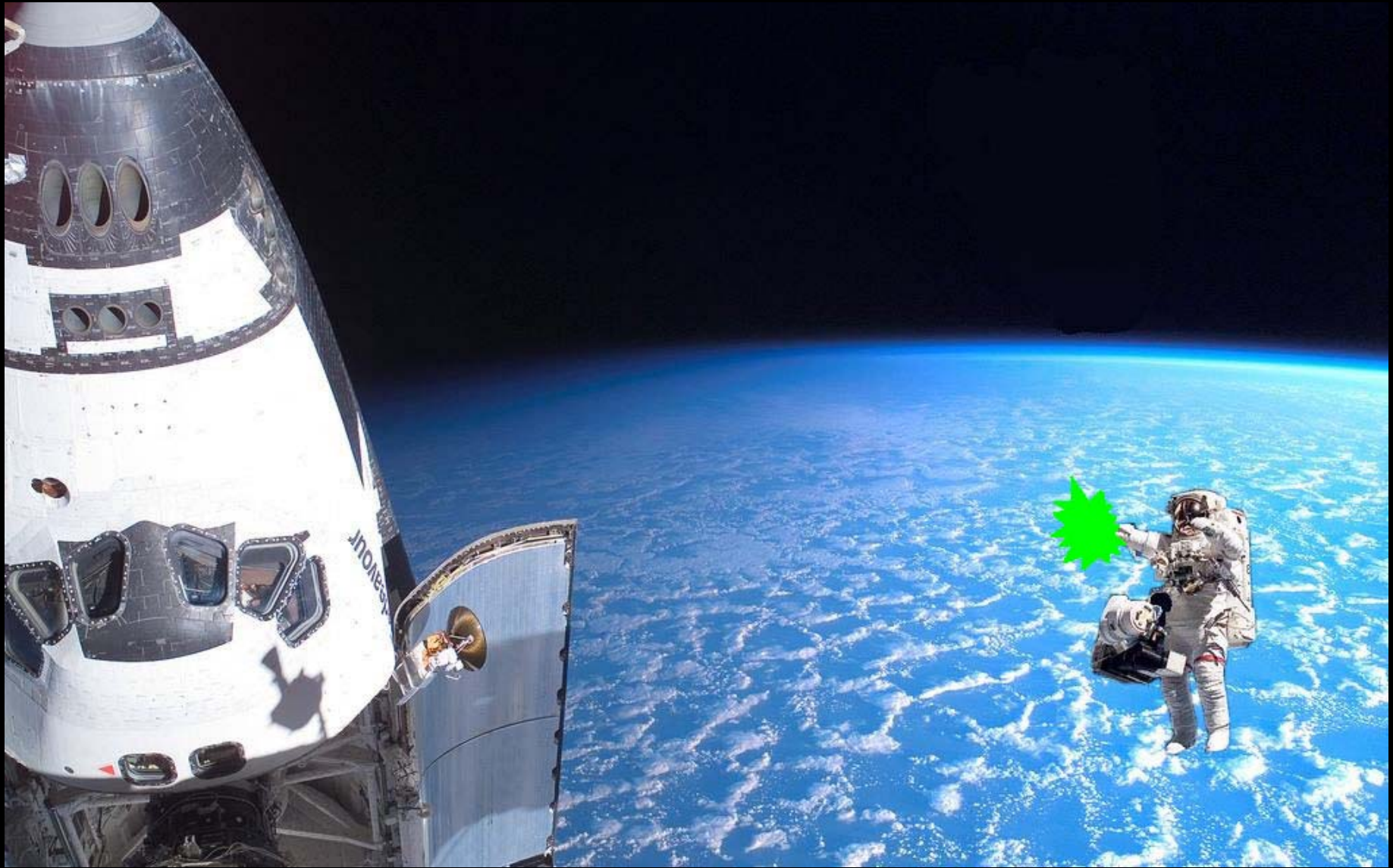


Photo Courtesy of NASA

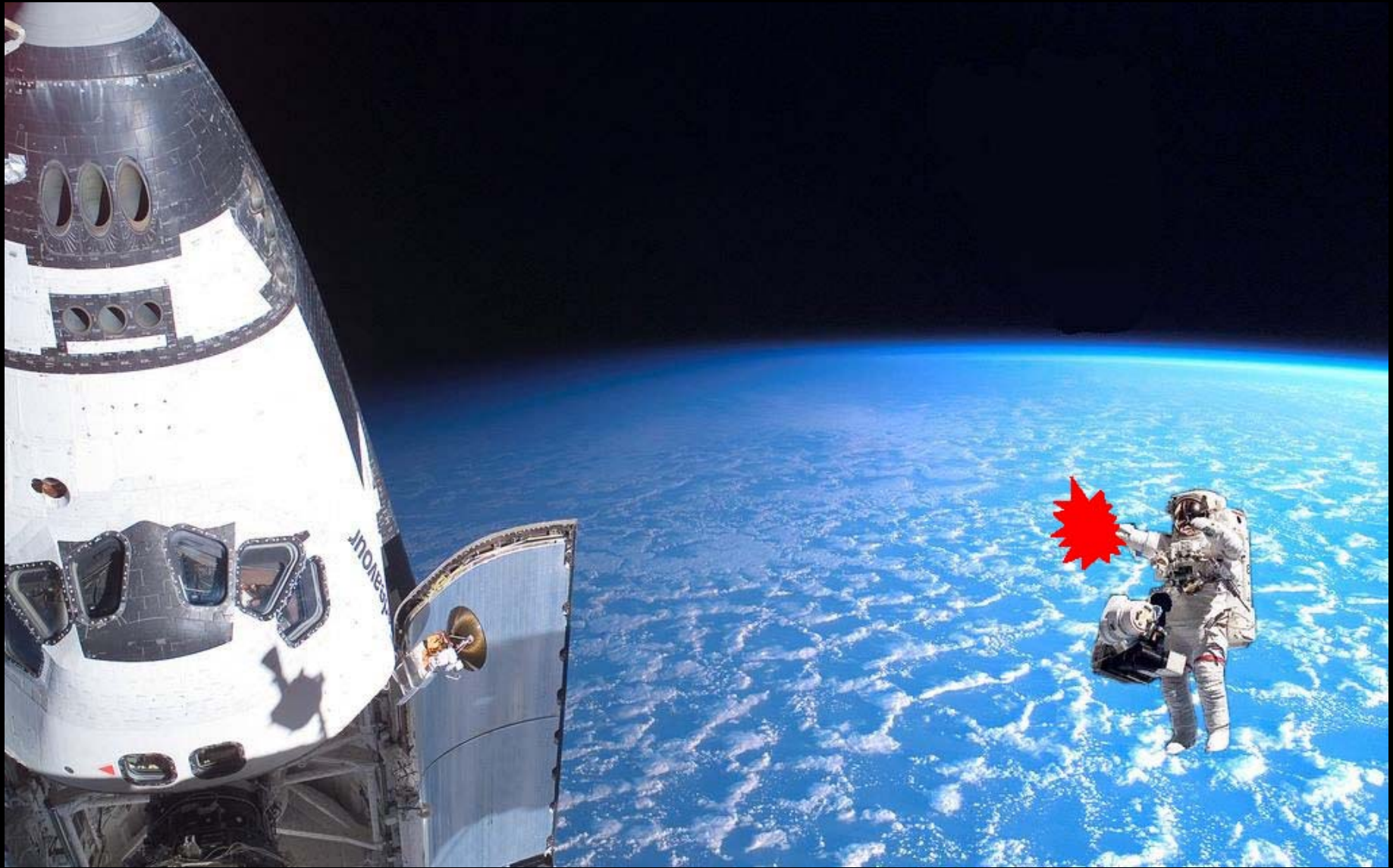


Photo Courtesy of NASA

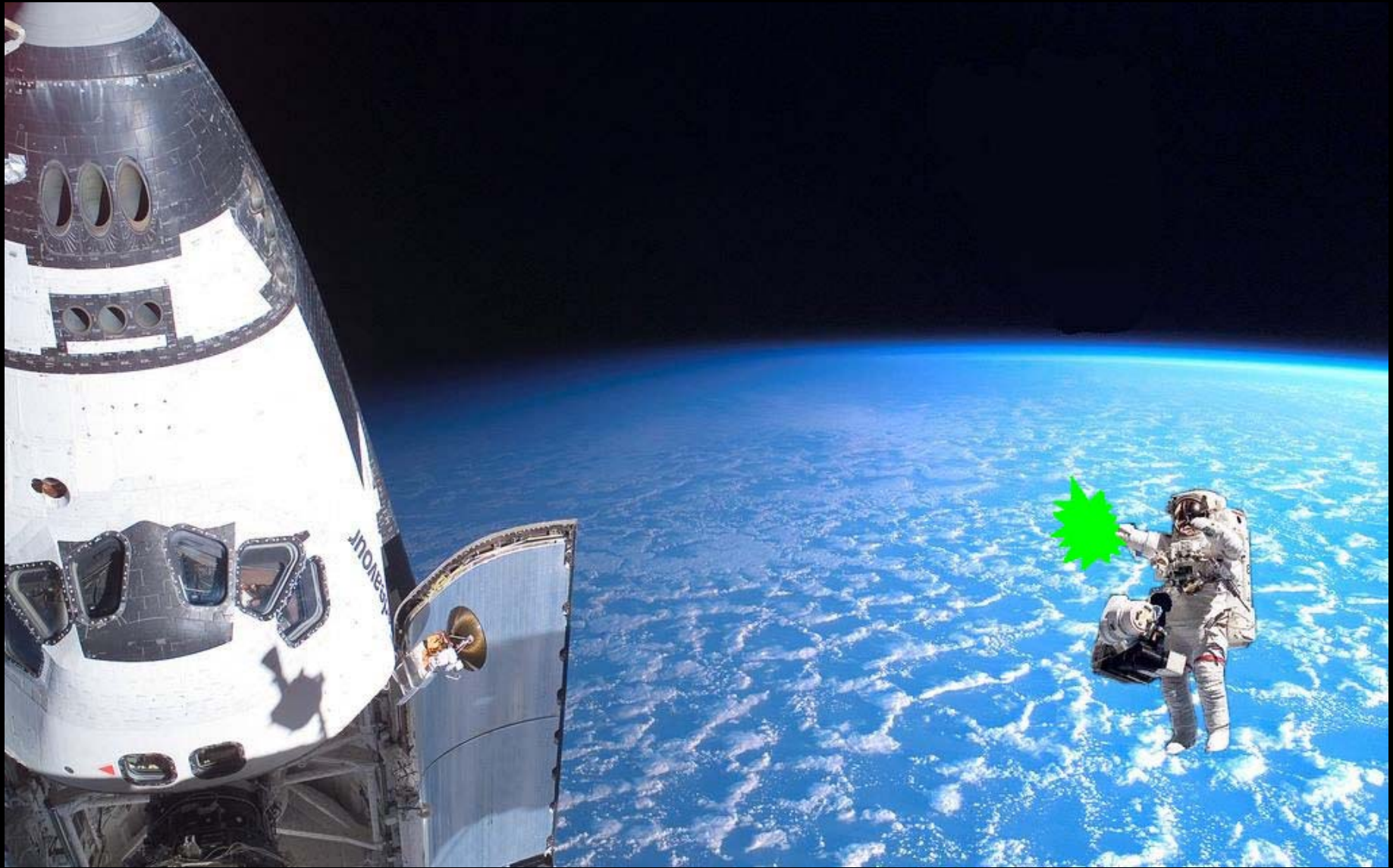


Photo Courtesy of NASA

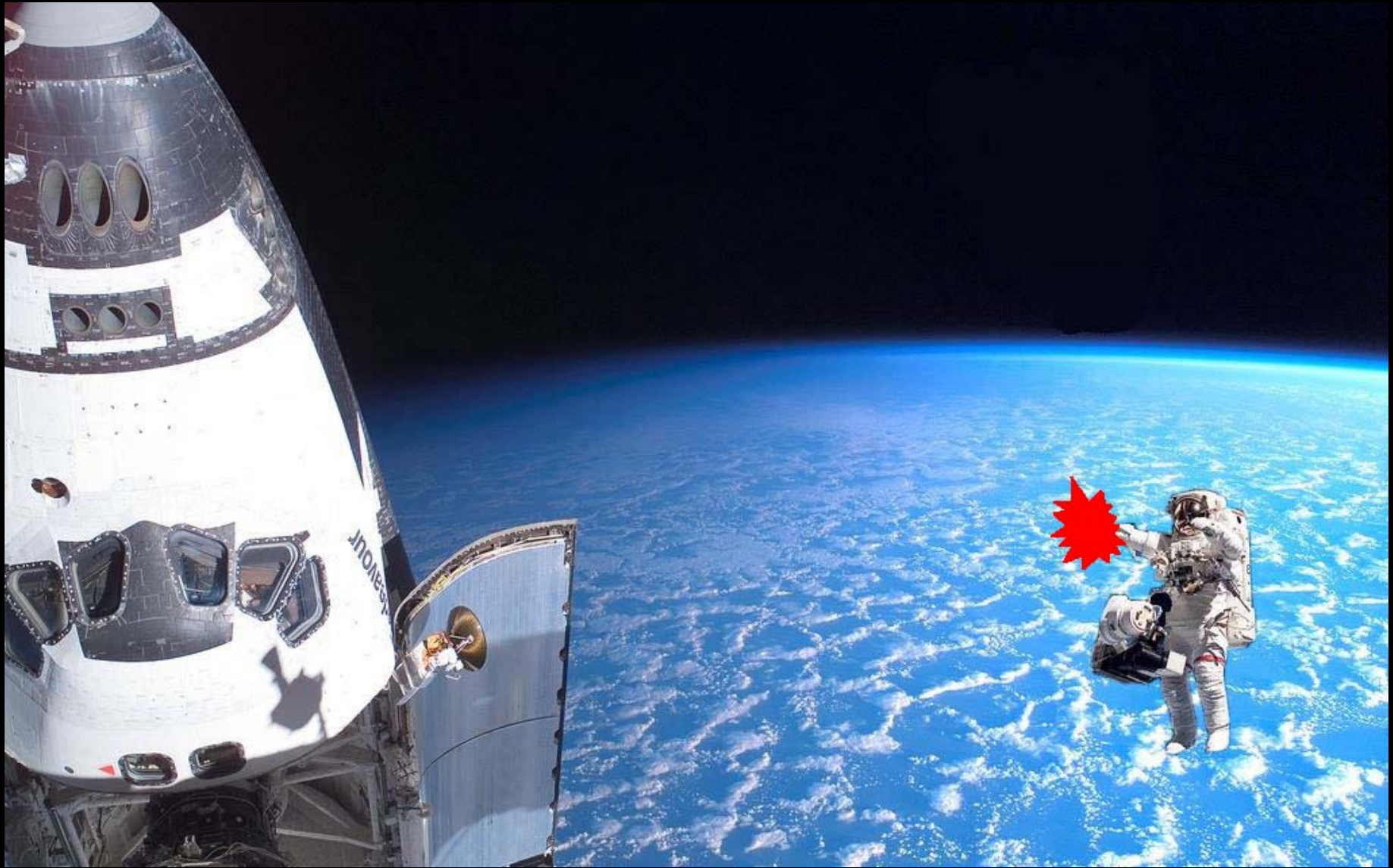
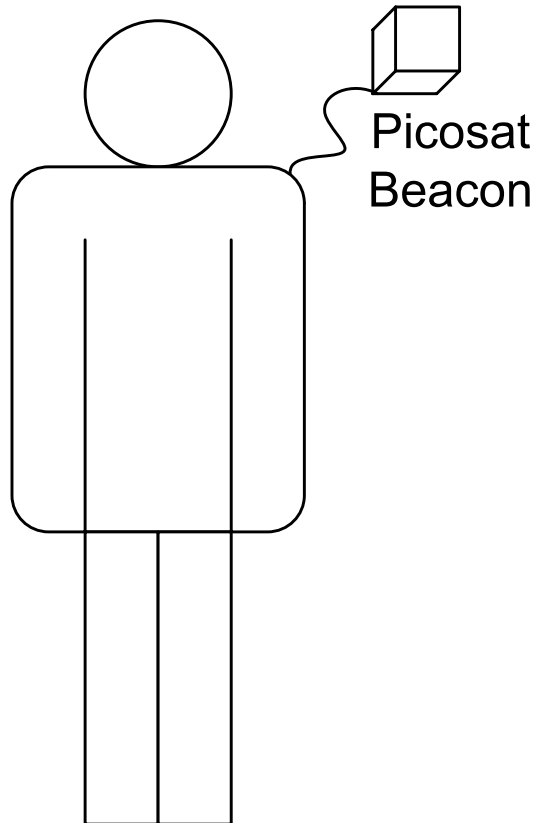


Photo Courtesy of NASA

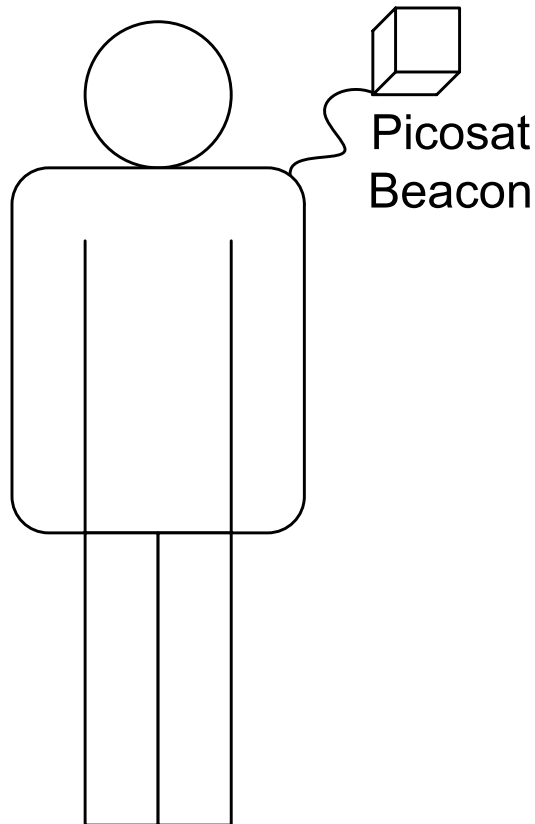
Beacon Prototypes

Picosat Beacon

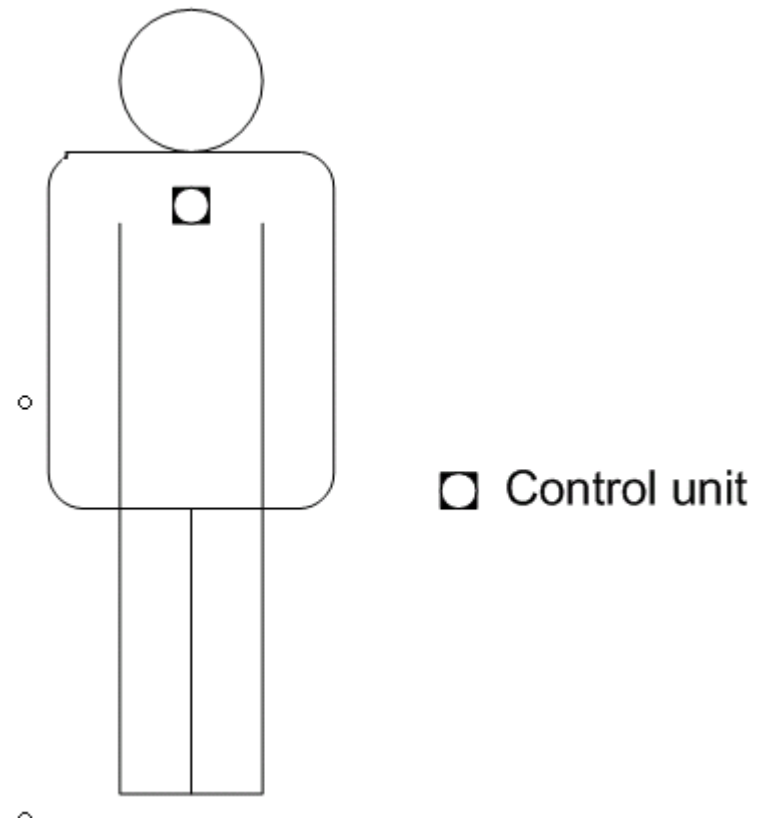


Beacon Prototypes

Picosat Beacon

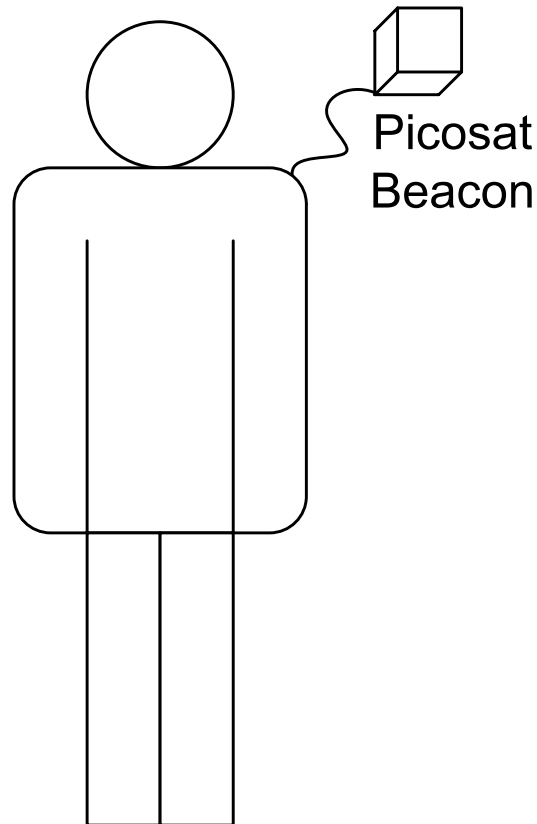


Distributed Wireless Beacon

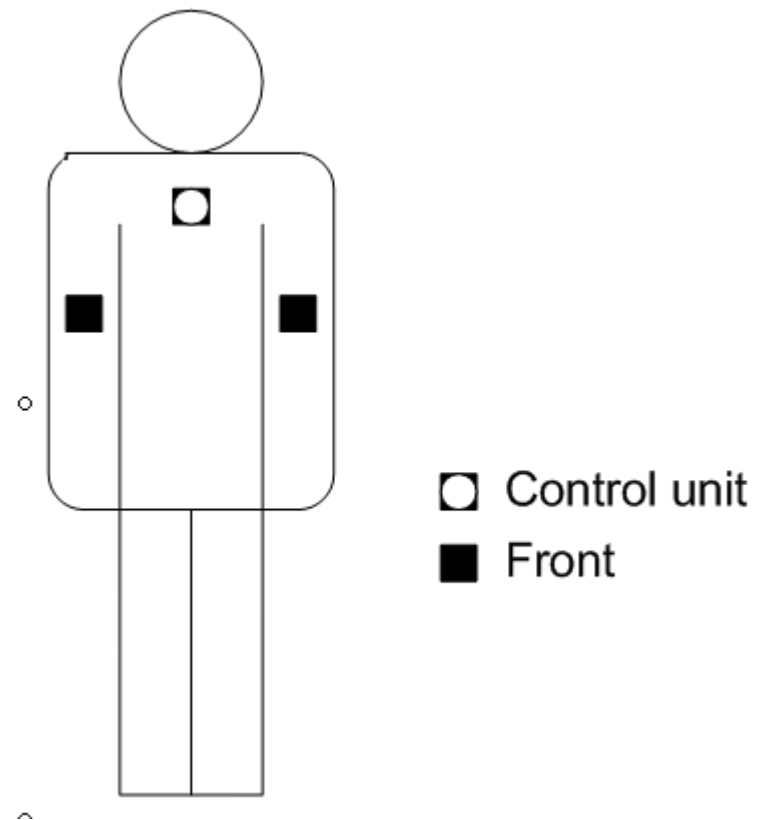


Beacon Prototypes

Picosat Beacon

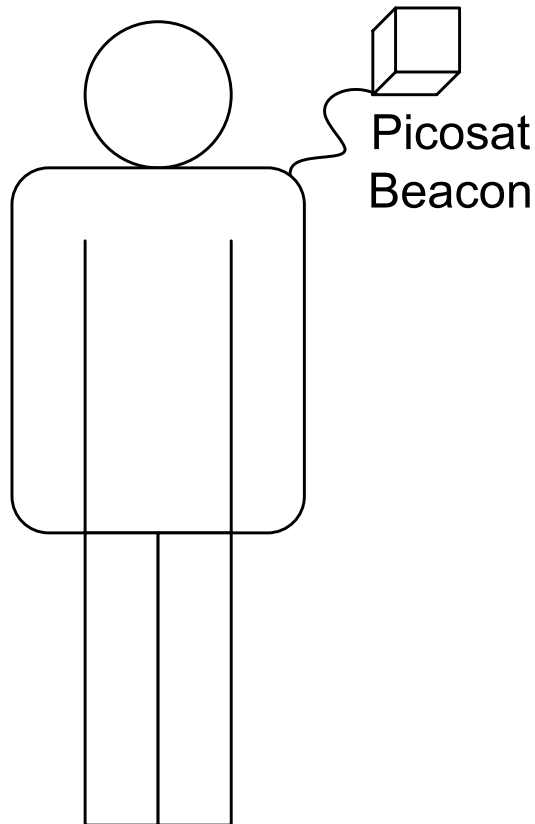


Distributed Wireless Beacon

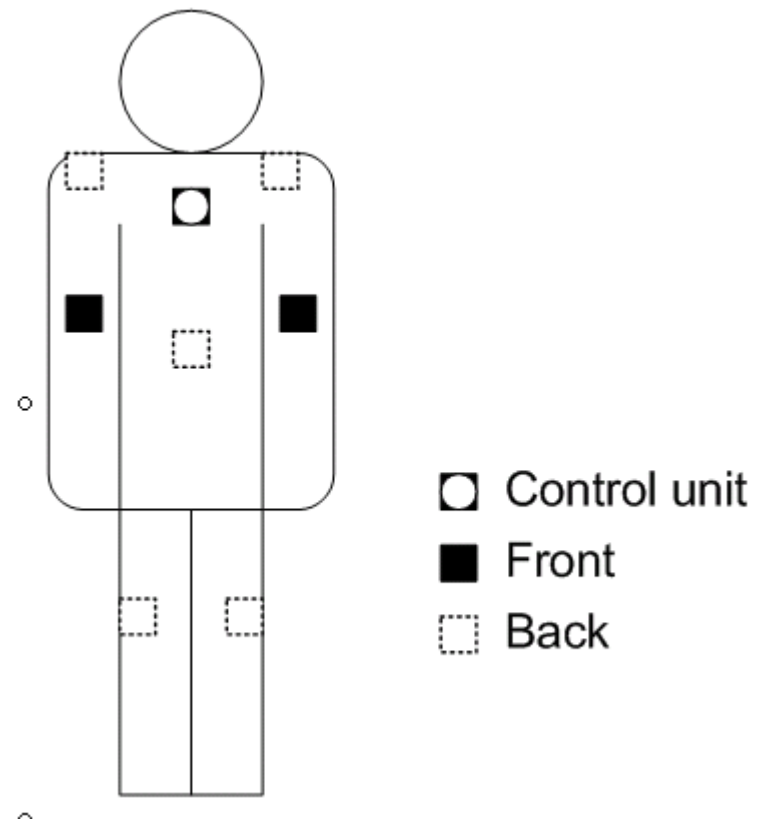


Beacon Prototypes

Picosat Beacon

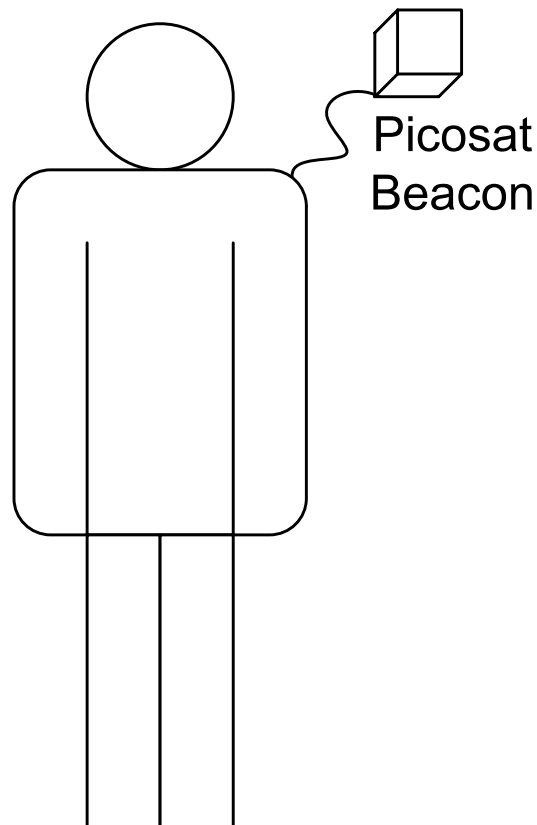


Distributed Wireless Beacon

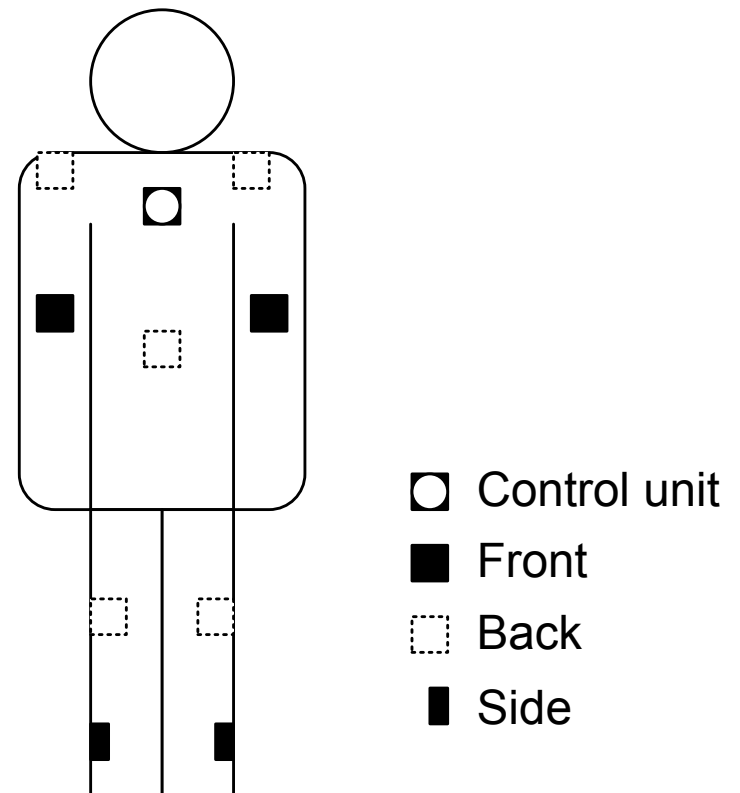


Beacon Prototypes

Picosat Beacon



Distributed Wireless Beacon



Picosatellite



Image by Aerospace Corporation's Aerocube-2

- Light, small satellites
 - Mass: 0.1 – 1 kg
 - Dimensions: 10 cm cube
- Low cost
 - Simple construction
 - Launched “Piggyback”
 - Multiple launched at once

Development Stages

- Optics Testing
 - Emitter Selection
 - Color and Strobe Visibility Testing
- Beacon Design
 - Picosat Beacon
 - Distributed Wireless Beacon
- Beacon Performance Testing

Emitter Selection

- Initial Light Source Candidates
 - Visible / IR LEDs
 - Xenon Flash Bulbs
 - Lasers
 - Incandescent
- Preliminary narrowed to LEDs

Visibility Testing

- LED Selection

Vendor	Color	Angle (degrees)	Power Consumed (W)	Power Delivered (μ watts)
lumex	green	0	1.19	1.61
lumileds	green	0	0.98	1.60
lumex	green	45	1.16	0.68
lumileds	green	45	0.93	0.95

- Color Selection:

- Volunteers compared visibility of blue, royal blue, green, cyan, and red LEDs
- Green LEDs most visible and selected

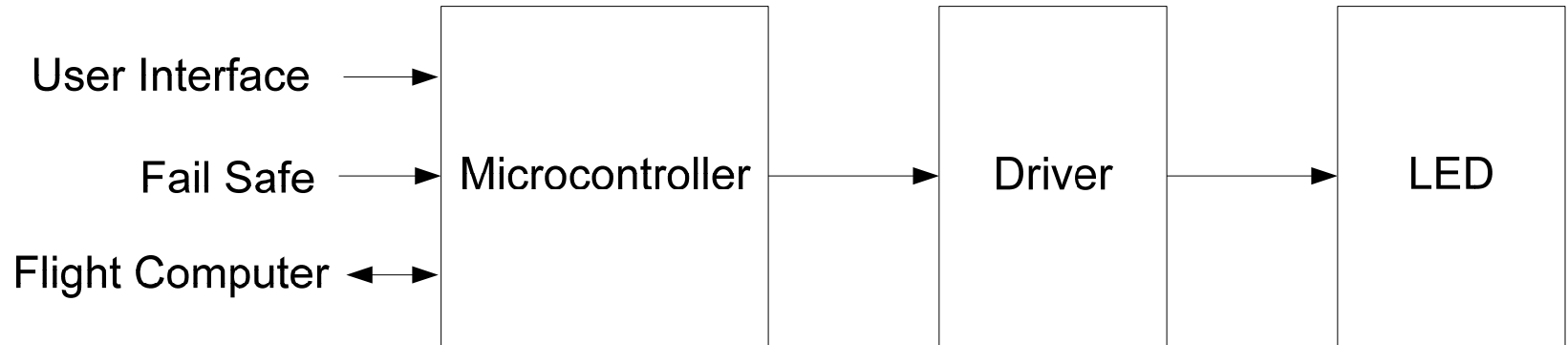
Visibility Testing: Strobe

- Observer Preferences

Test	A	B	#A	#B	No Diff
4	3 Hz	10 Hz	0	4	2
5	3 Hz	5 Hz	1	3	2
6	10 Hz	5 Hz	0	5	1
7	1 Hz	3 Hz	1	5	1
8	2 Hz	5 Hz	1	3	2
9	5 Hz, 20%	5 Hz, 50%	3	0	3
10	5 Hz, 20%	5 Hz, 80%	6	0	0

LED most visible at 5 Hz, 20% duty cycle

Picosat Beacon



User selects display mode via user interface

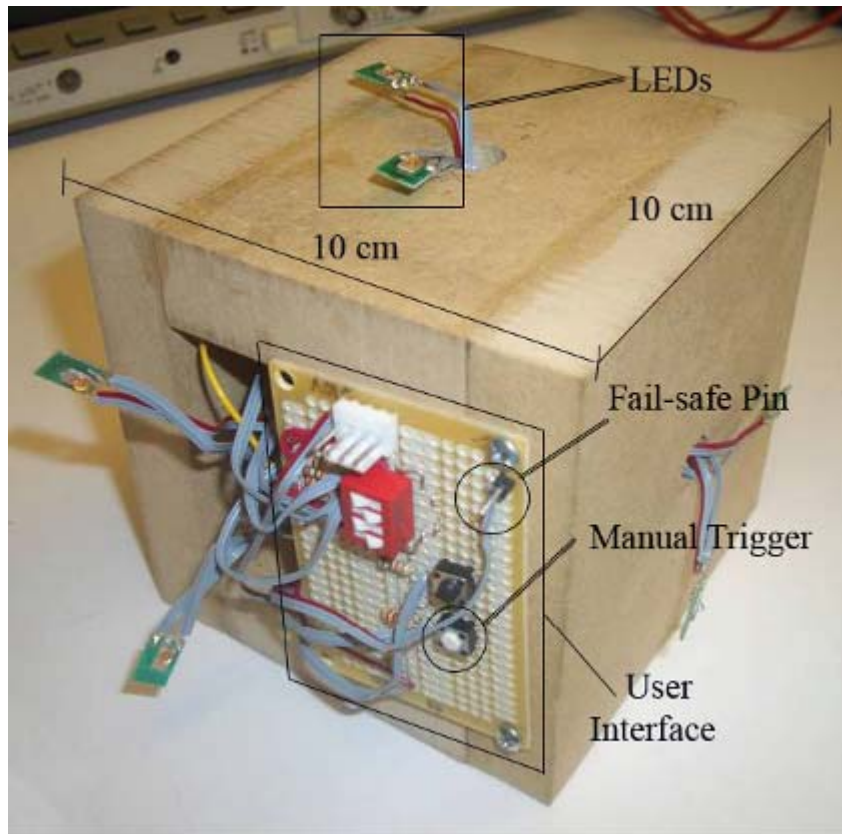
Beacon triggered by fail safe (e.g. connected to a medical sensor) or user interface

Microcontroller communicates emergency to picosat flight computer

Microcontroller toggles driver enable pin according to display mode

LED visually communicates the emergency

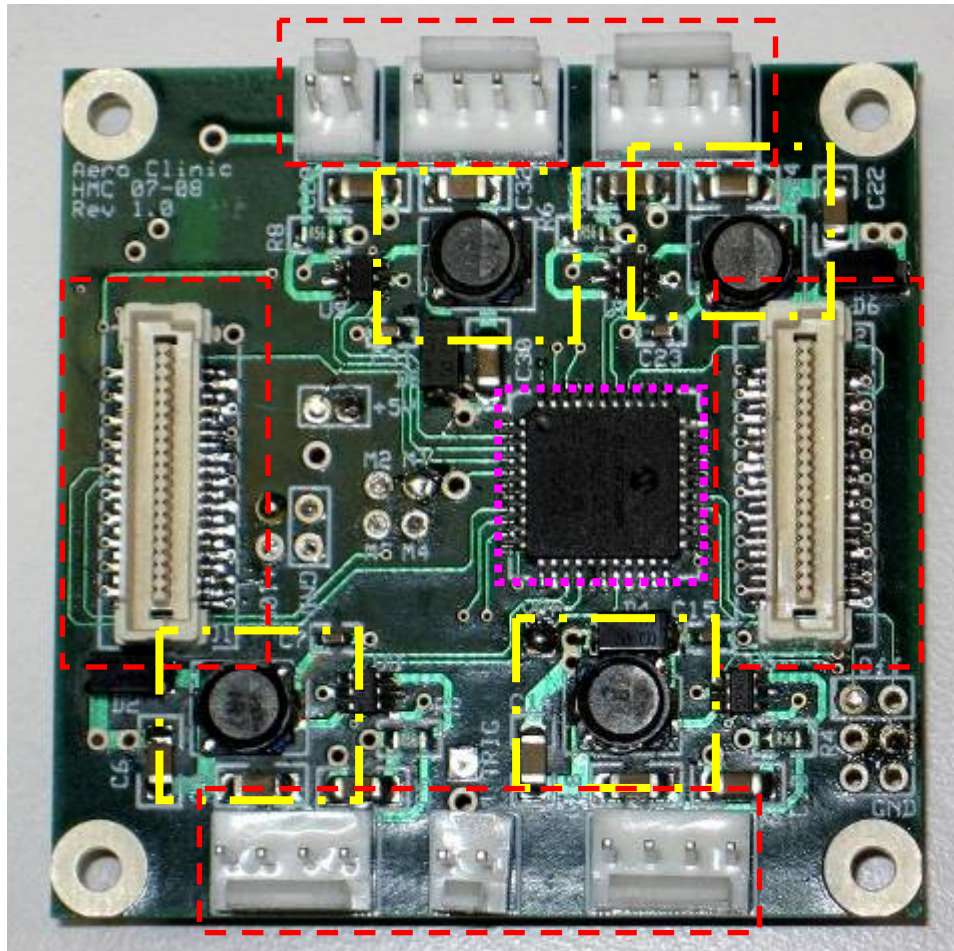
Picosat Beacon



- Per Picosat Specifications
- Low Power / High Efficiency
 - Low Power Microcontroller
 - Active: 5.3 mA
 - Sleep: 0.1 μ A
 - Buck Current Regulator
 - Time Share Coding Scheme
- 18 LEDs Total
 - 6 Green, 6 Red, (6 IR)
- Modes:
 - S.O.S.
 - 5 Hz Strobe
 - Fail-safe
- Runs for 3.5 hrs (Strobe Mode)

Picosat Board

5.6 cm



Weight: 20 g

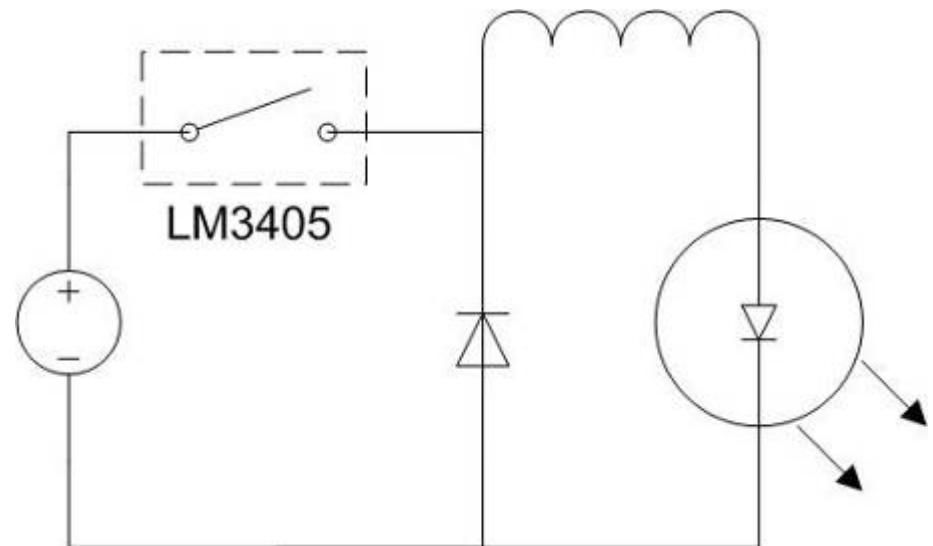
■ Microcontroller

■ Drivers

■ Connectors

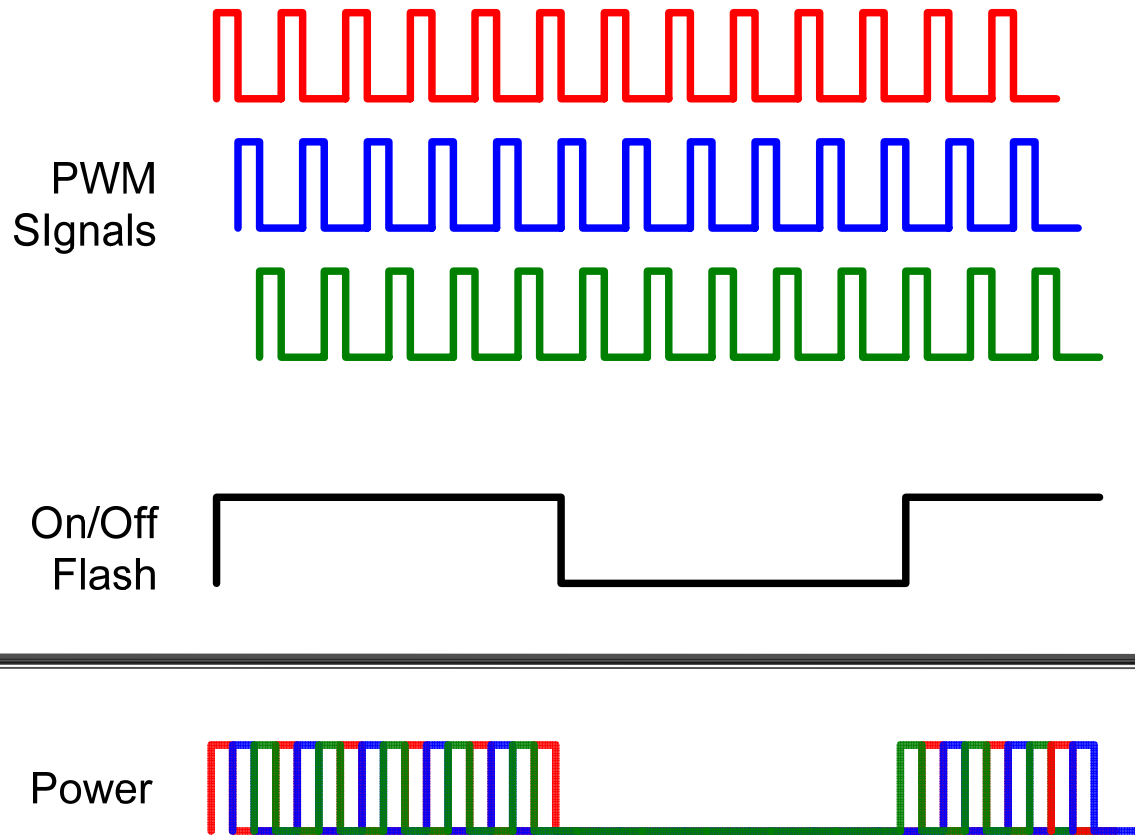
Drivers: Buck Current Regulator

- Overview
 - NS LM3405
 - Constant current source
 - Operates at 1.6 MHz
- Advantages:
 - High efficiency
 - Pulse-Width Modulation (PWM)/enable pin
 - Small footprint
 - 3mm x 1.7mm



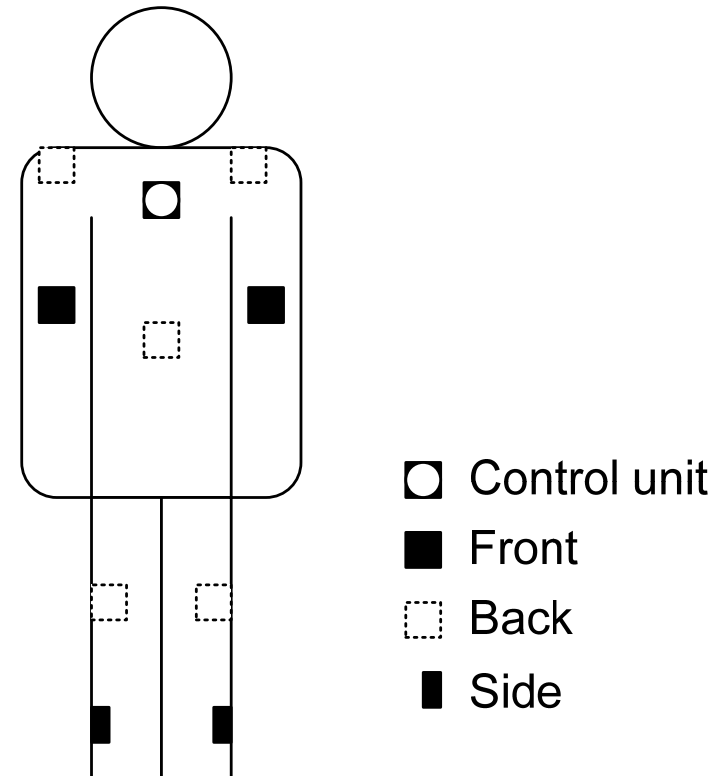
85% efficiency for two Luxeon LEDs in Series

Time Sharing

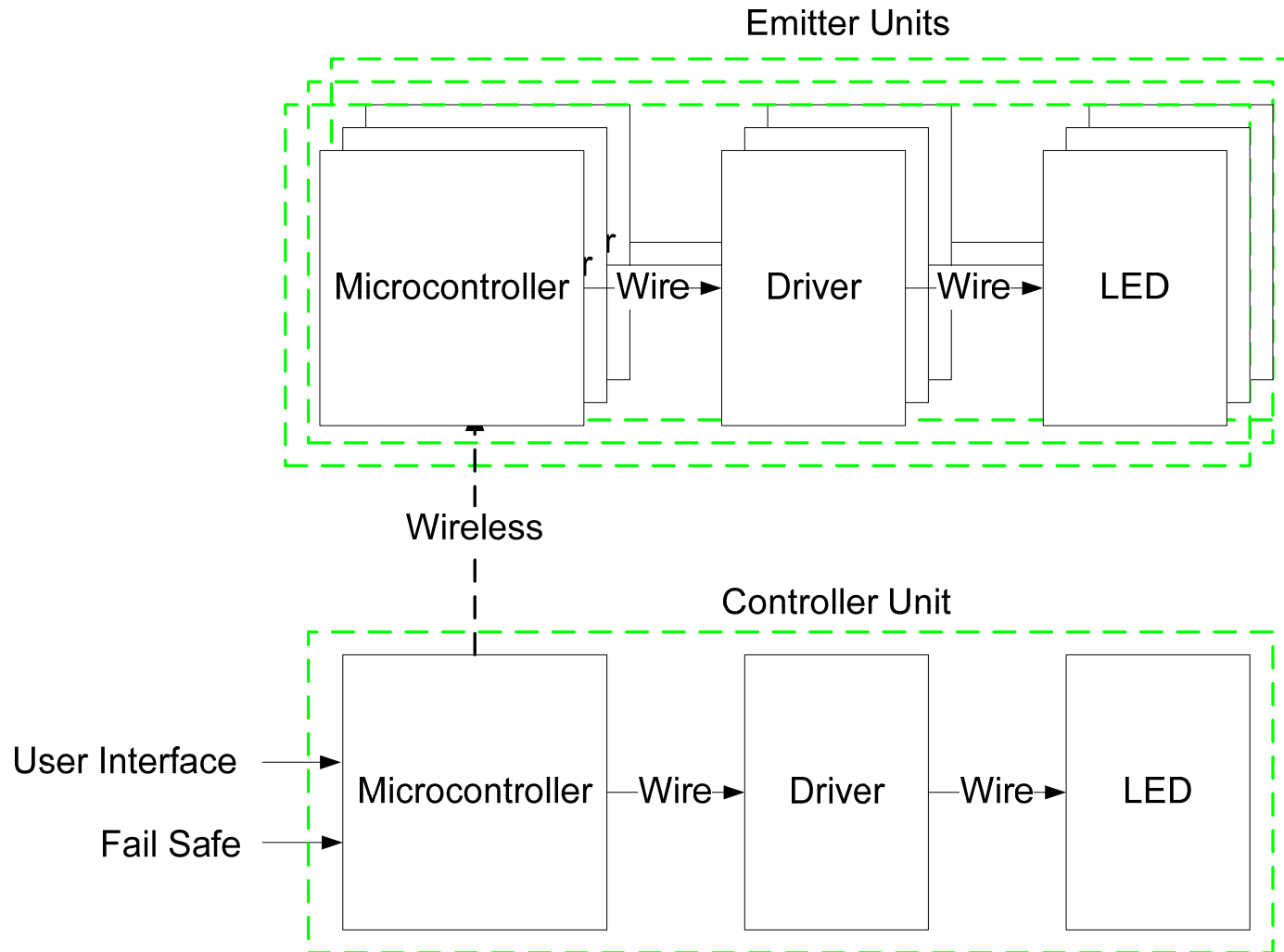


Distributed Wireless Beacon

- Simplicity of Construction
- Connectivity to Spacesuit
- Minimal Obstruction
- Maximal Visibility



Distributed Wireless Beacon



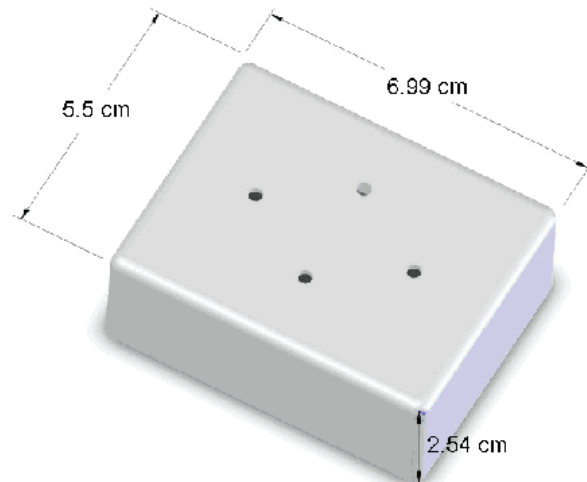
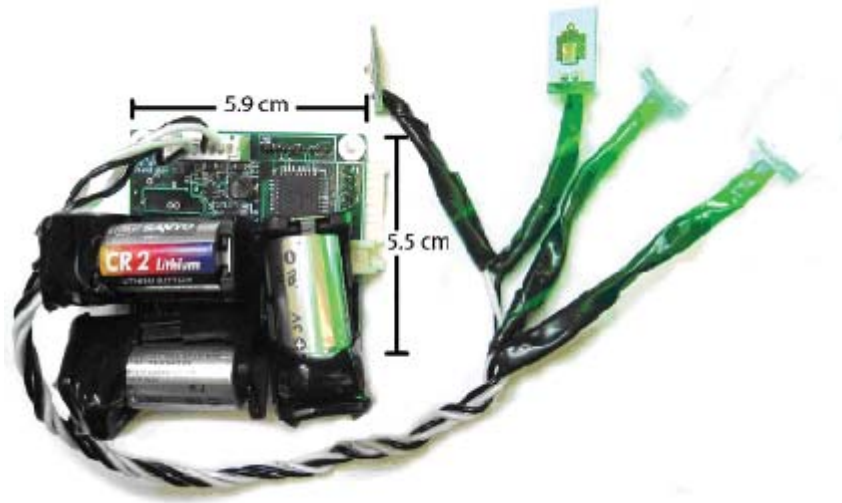
Wireless

SparkFun module

- Nordic nRF24Lo1 Chip
- 2.4 GHz transceiver
- 50 m range
- SPI interface
- Size ~on the order of a quarter

- 30 mW transmit
- 60 μ W standby

Distributed Wireless Beacon



- Small Size
- Low Power / High Efficiency
 - Same as Picosat Beacon
 - μ Watt 2.4 GHz Wireless
- Up to 6 LEDs per Module
 - 2 Green, 2 Red, 2 IR
- Modes:
 - S.O.S.
 - 5 Hz Strobe
 - Fail-safe
- Runs for 31 hrs (Strobe Mode)
- 8-bit Packet Drop Rate: 3.3%

Beacon Performance Testing

- Power Consumption

Mode	Picosat Beacon		Distributed Wireless Beacon	
	Power (W)	Duration (hr)	Power (W)	Duration (hr)
Idle	0.03 W	170 hr	0.03 W	260 hr
Strobe	1.44 W	3.5 hr	0.24 W	31 hr

- Visible Performance

- Daytime Visibility: 110 – 160 meters
- Nighttime Visibility: >800 meters*

*Limited due to test site location.

Heat Dissipation

- Black Body Radiation: $q = \sigma \varepsilon (T_h^4 - T_c^4)$
 - q : Power dissipated per square meter
 - σ : Stefan-Boltzmann Constant
 - ε : Material emissivity constant (0.76)
 - T_h : Temperature of radiative body
 - T_c : Temperature of surroundings

Prototype	Required Area (cm ²)	Available Area (cm ²)
Picosat Beacon	216	600
Distributed Wireless Beacon	48	70

- Worst-case with 0% efficient LED

Conclusions

- Designed, built, and tested two distress beacon prototypes
 - Visible from 110-160 m at noon, >800 m at night
 - Runs for 31 hrs (Wireless Beacon) or 3.5 hrs (Picosat Beacon) in strobe mode

Future Work

- Integrate wireless chip with system board
- Develop analytic visibility model
- Explore alternate light sources and reflectors
- Integrate beacon with spacesuit

Acknowledgments

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 - Dr. David J. Evans
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- NASA Astronauts
 - C. Gordon Fullerton
 - Dr. Stan Love '87
 - Dr. George Nelson '72
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Questions?

Photo Courtesy of NASA