



THE NOT SO SILENT WORLD OF LIVING AND WORKING IN SPACE:

The Challenges of ISS Noise

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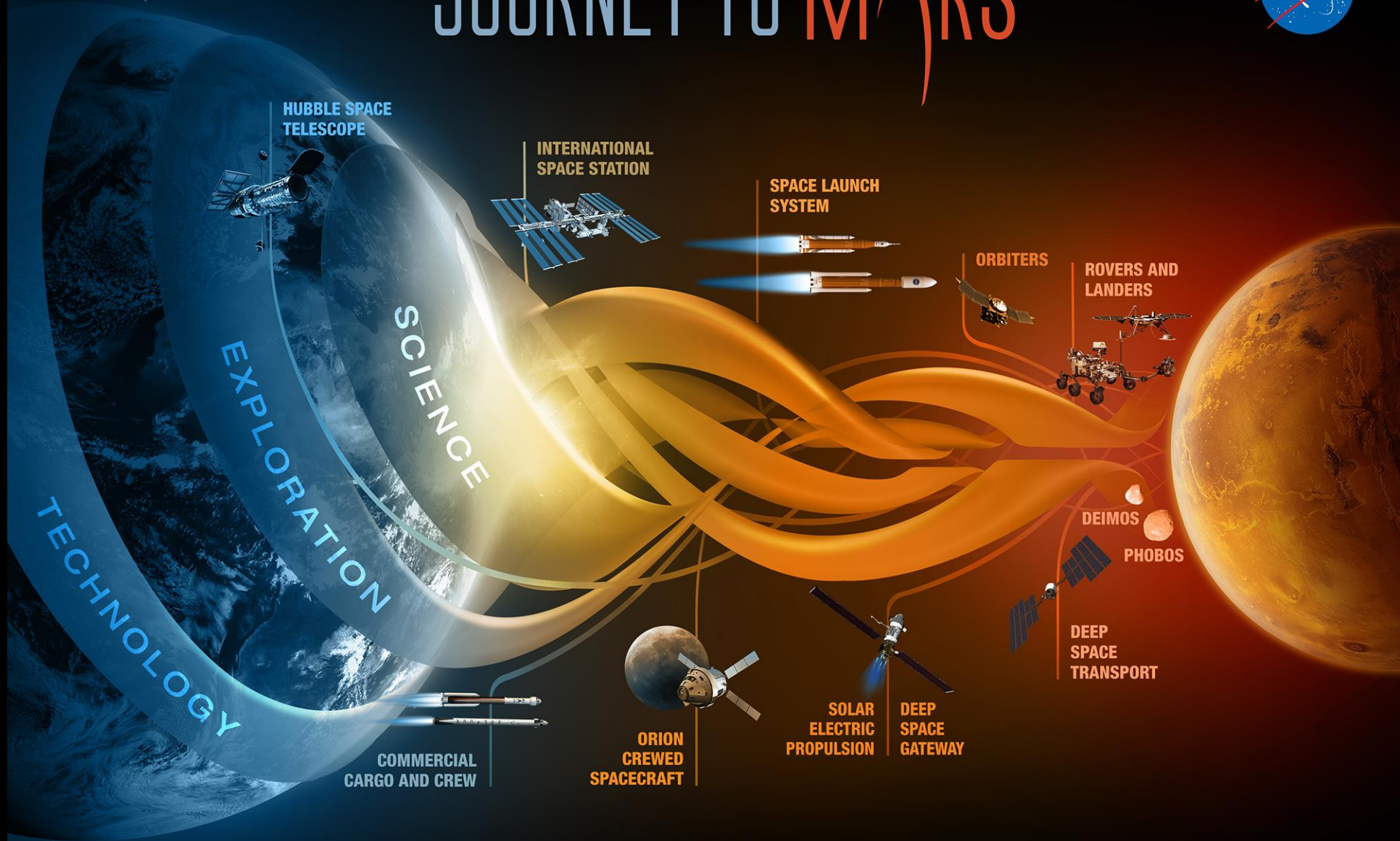
Christopher S. Allen



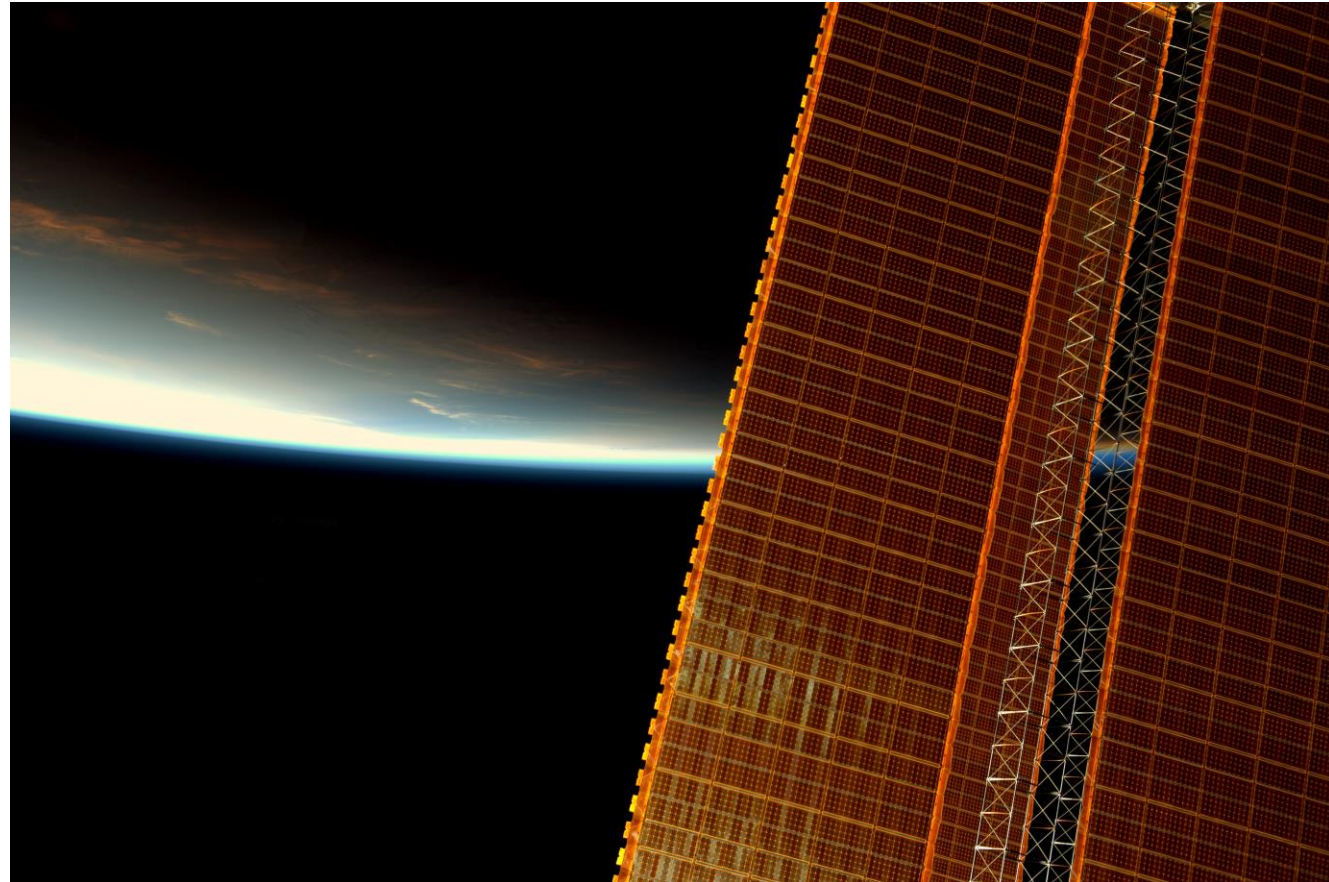
- **I have no financial obligation to any company or organization.**
- **The opinions shared are my own and not those of NASA, the US government, any starship federation, or rebel alliance.**



JOURNEY TO MARS



- **Commercial Aviation Noise**
- **Military Aviation Noise**
- **Spaceflight Noise**
 - Historical Perspective of ISS Noise
 - Current status
- **Noise Monitored**
- **Noise Controlled**
- **Spaceflight Related Hearing Loss**
- **Reflections On Noise On ISS**



Commercial Aviation Noise



- **Aircraft**

- In Flight: 80-85 dB(A)
- Landing: 75-80 dB(A)
- *Ozcan and Nemlioglu (2006)*



- **Ground Power Equipment**

- **Support Equipment**



Military Aviation Noise



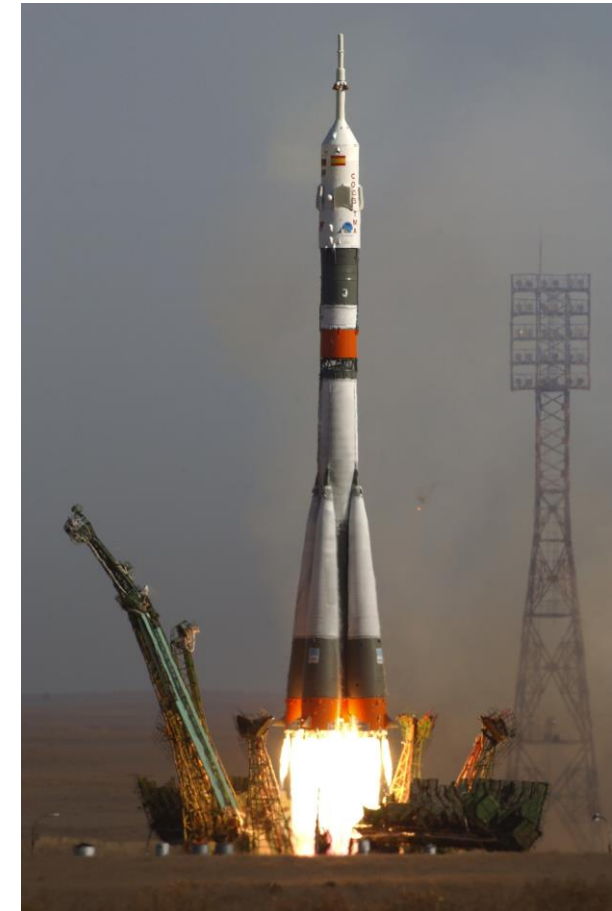
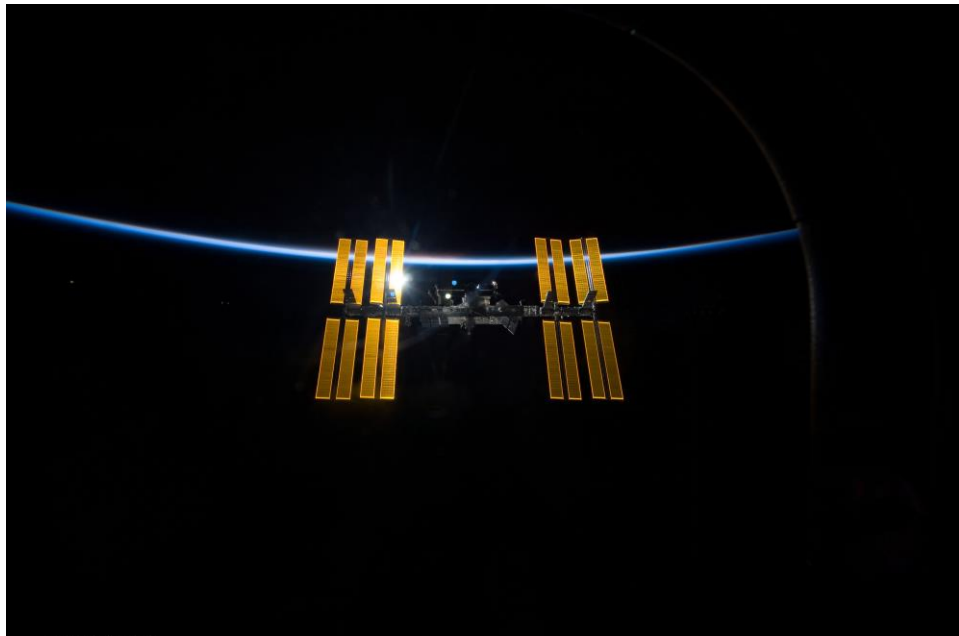
- **Aircraft Noise**
- **Ground Power Systems**
- **Support Systems**
- **Weapons Systems**



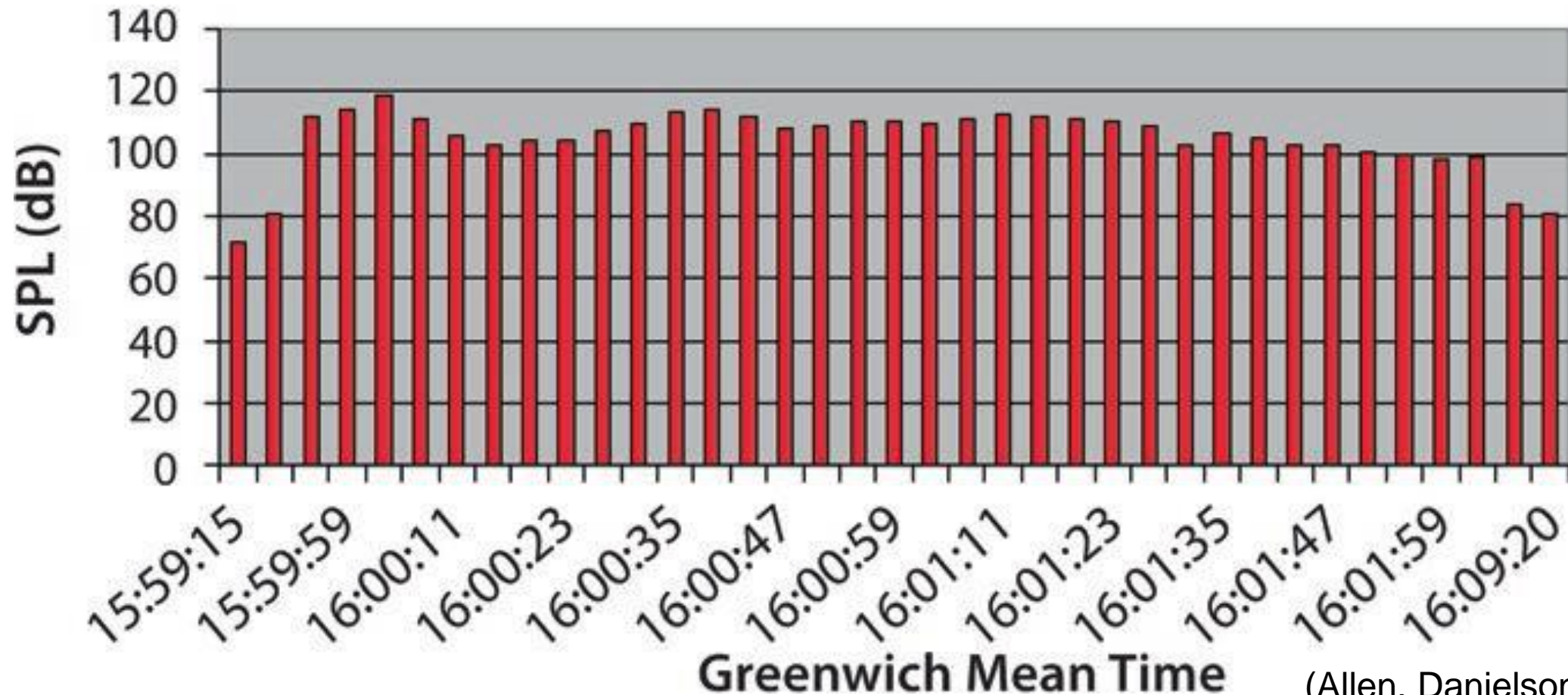
Spaceflight Noise



- **Spacecraft Noise at Launch**
- **Spacecraft Operational Flight Noise**



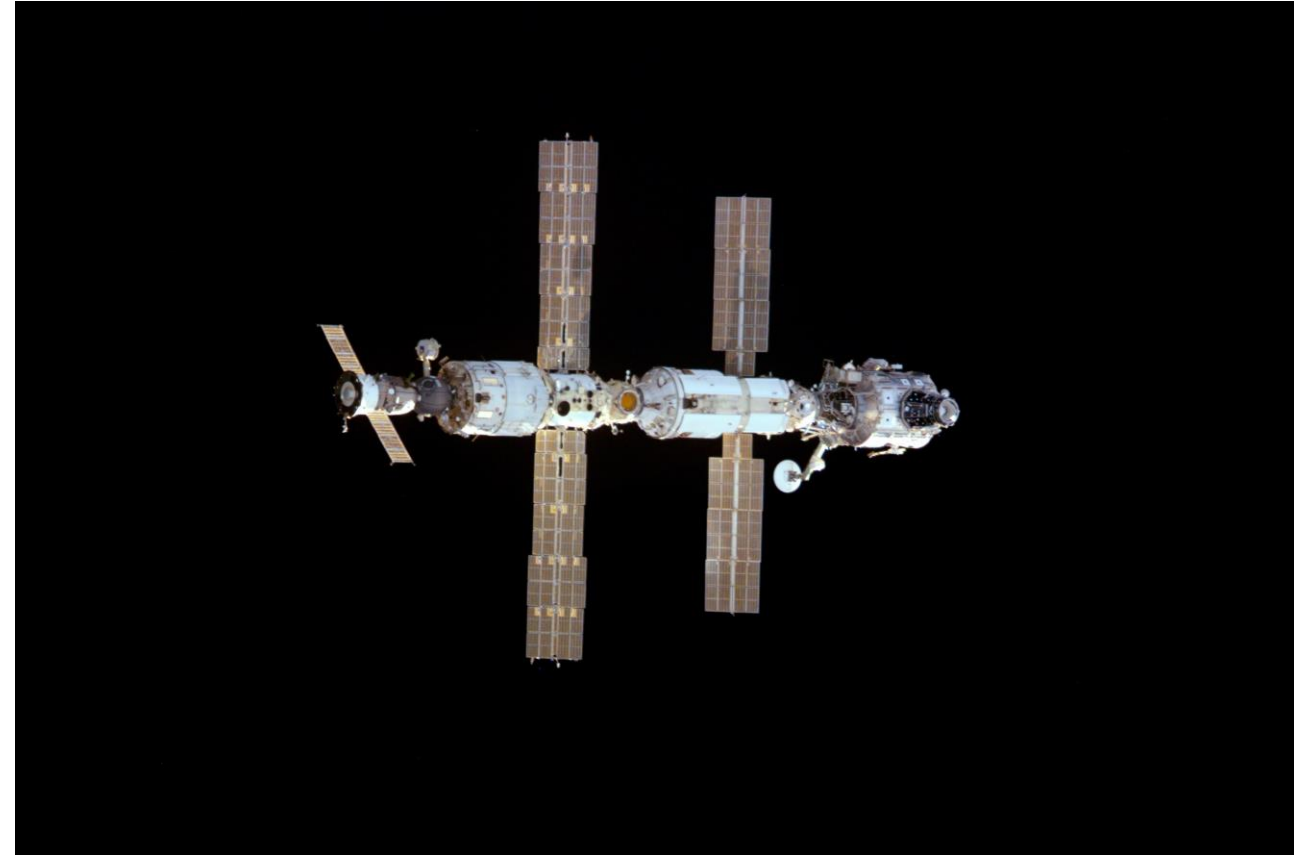
LAUNCH Noise Levels (Flight Deck) (Data: STS-3 Columbia)



Historical Perspective of ISS Noise



- The first two modules of the ISS were joined together in 1998
- Continuously inhabited since 2000
- Russian Space Module with sound levels mostly in the range of 67–73 dBA
- Acoustic environment considered one of the top habitability concerns on ISS
- Concern that making Hearing Protective Devices (HPDs) readily available on the ISS would result in higher noise levels
- Sense that HPDs could correct for any *exceedances* of the standards

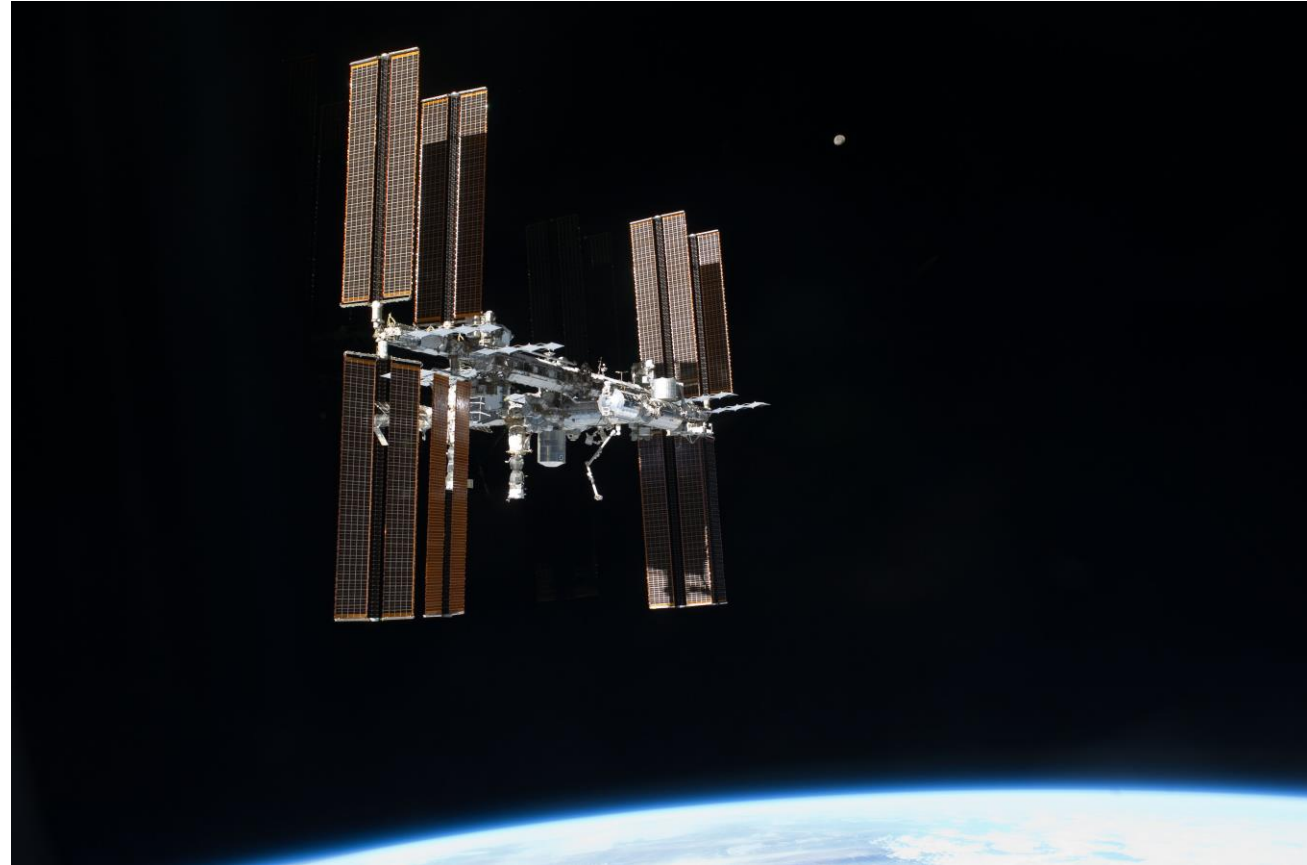


(Photo courtesy of NASA)

Historical Perspective of ISS Noise



- *ISS Acoustics Working Group* and the *Multilateral Medical Operations Panel Acoustics Subgroup*
 - Formed to work ISS acoustics issues
- Sets Standards
- Assures Compliance
- Hearing Protection is Used, But No Longer Used as a Crutch

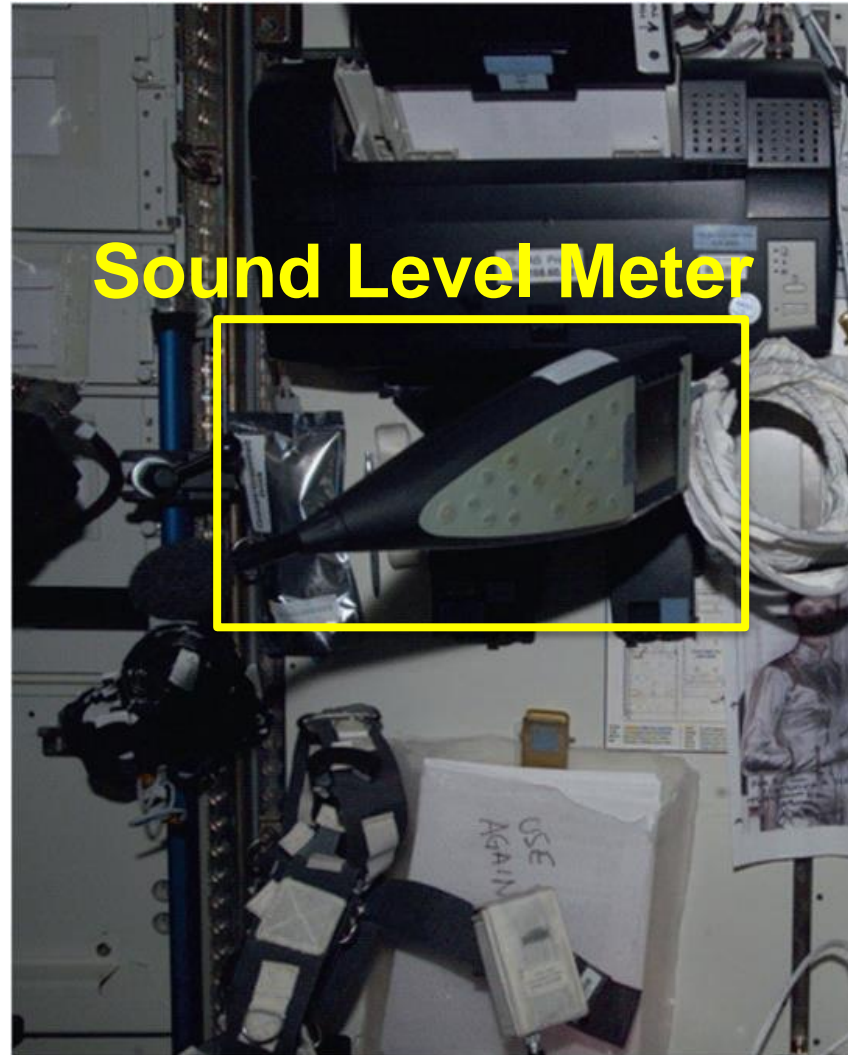


(Photo courtesy of NASA)

Noise Monitored

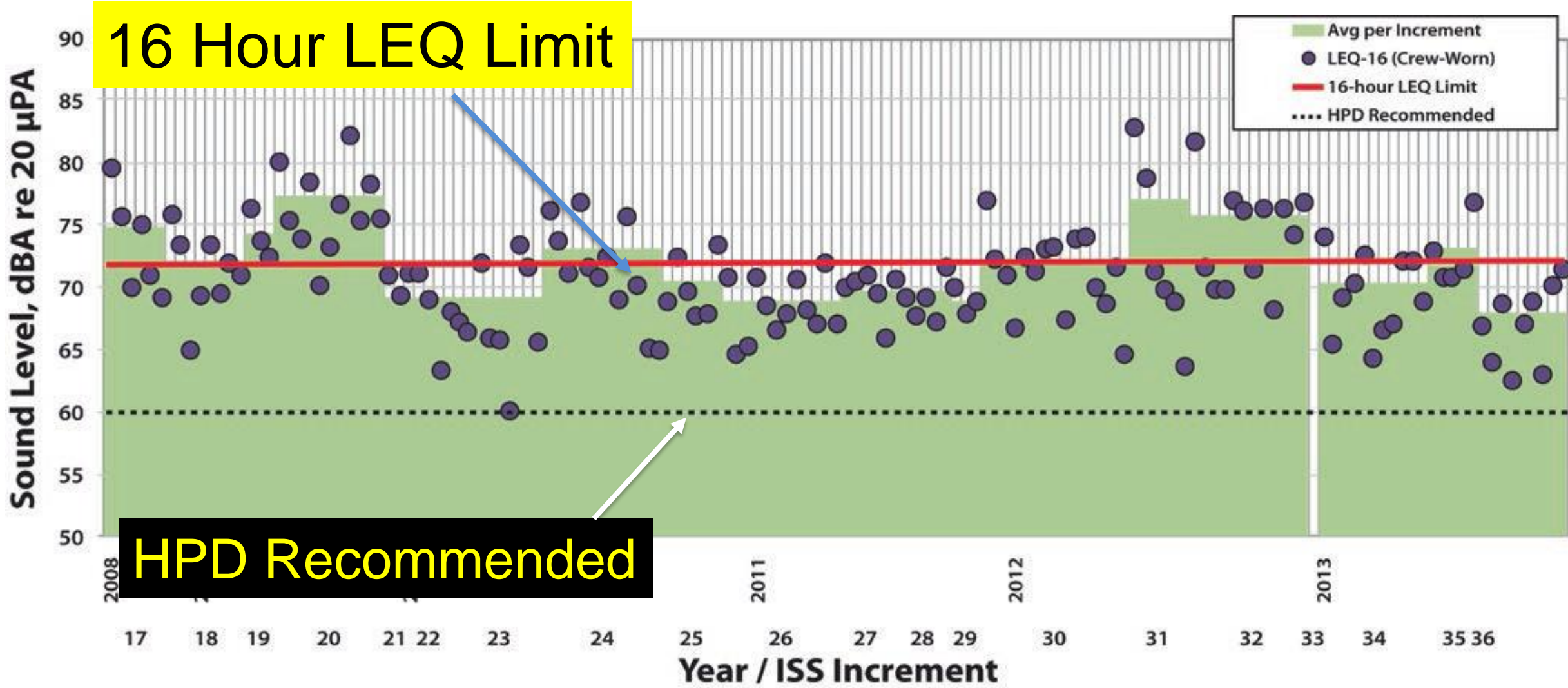


- **Noise measured with Sound Level Meter**
 - Continuous noise in each module is measured
- **Individual exposures measured with crew-worn Acoustic Dosimeter**
 - Measure Time-Weighted Average
 - 16 hour work period
 - 8 hour sleep period
 - Integrates measurements of continuous and intermittent noise



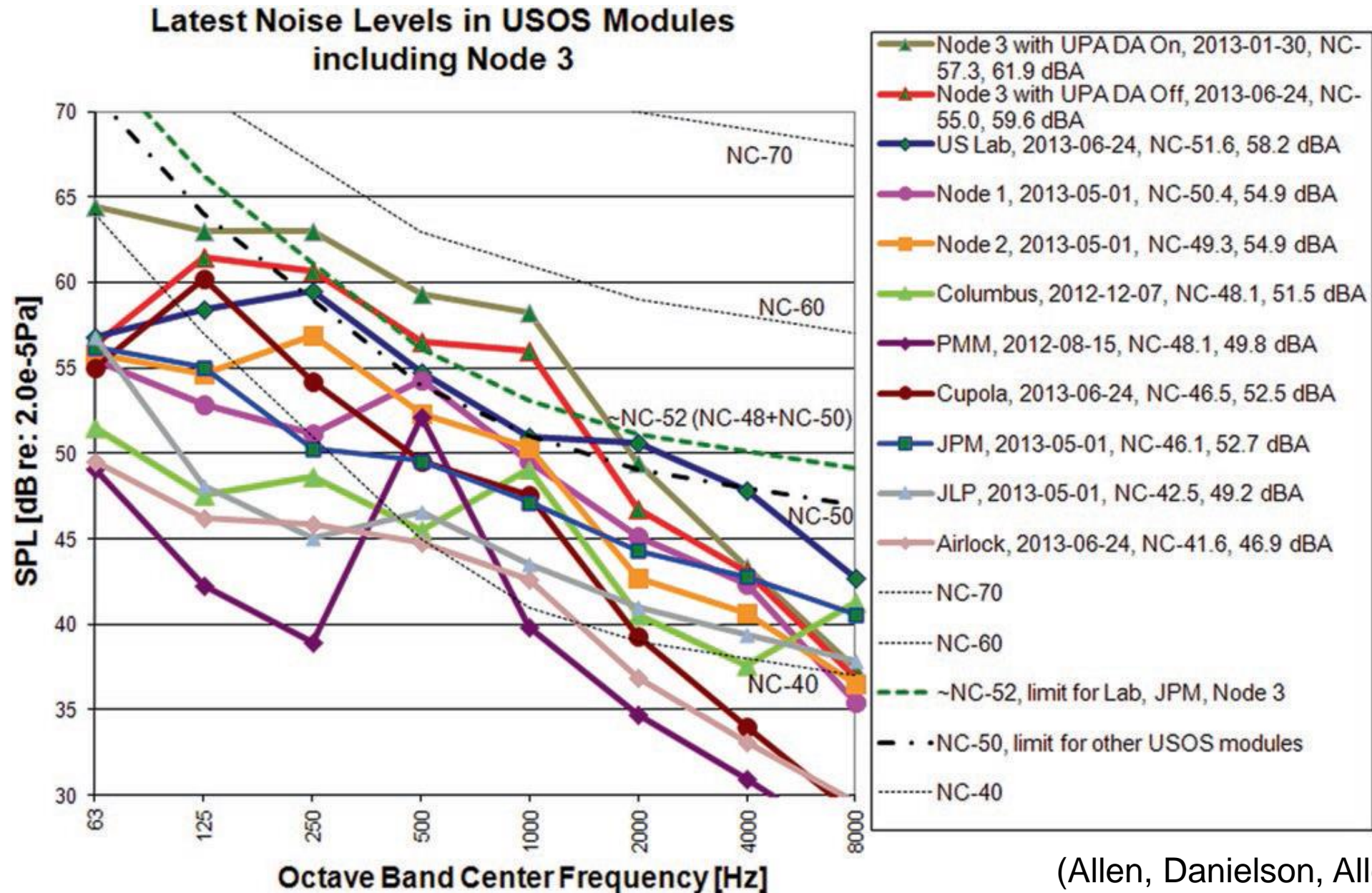


ISS Noise Exposure Measurements

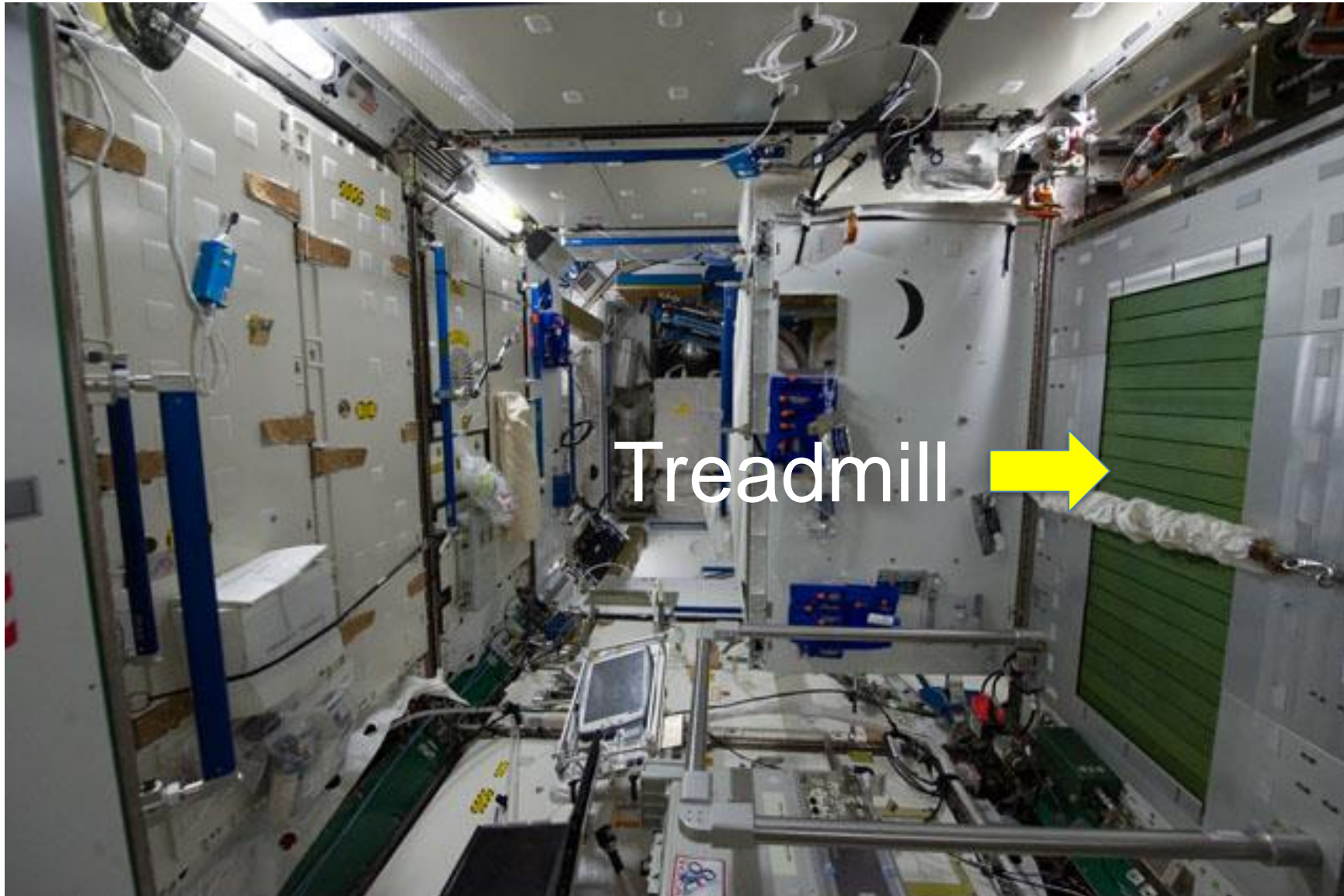


(Allen, Danielson, Allen, 2016)

Continuous Noise Monitored



On-Orbit Anomalies – T2 Treadmill



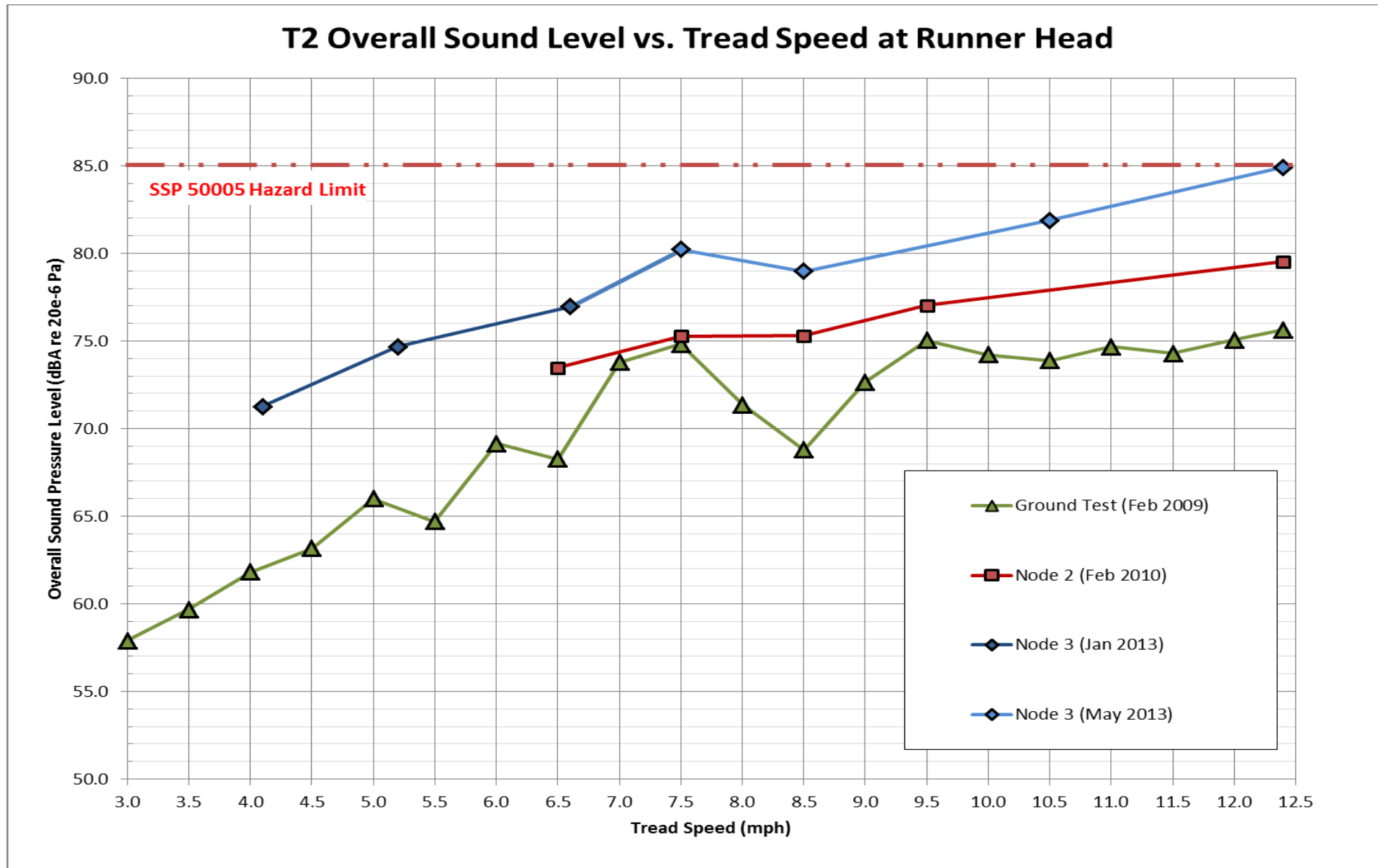
Treadmill



ISS023E053664

(Courtesy NASA)

On-Orbit Anomalies – T2 (Treadmill)



Quiet Fan Development



| Fan type | Original Fan | Quiet Fan |
|----------------------------|-----------------|-----------------|
| Pressure Rise, mm H2O | 4 (0.16 in H2O) | 4 (0.16 in H2O) |
| Flow Rate, Q, l/s | 47.0 (100 cfm) | 83.4 (176 cfm) |
| Current Draw, mA | 470 | 470 |
| Rotation speed, rpm | 3120 | 2010 |
| Isolated noise levels, dBA | 61-64 | 48 |

61-64 dBA  48 dBA

08-11-09 17:02

(Courtesy NASA)

Ventilation Fan Cleaning



Japanese Pressurized Module
Stbd Fwd IMV Fan (Inlet)



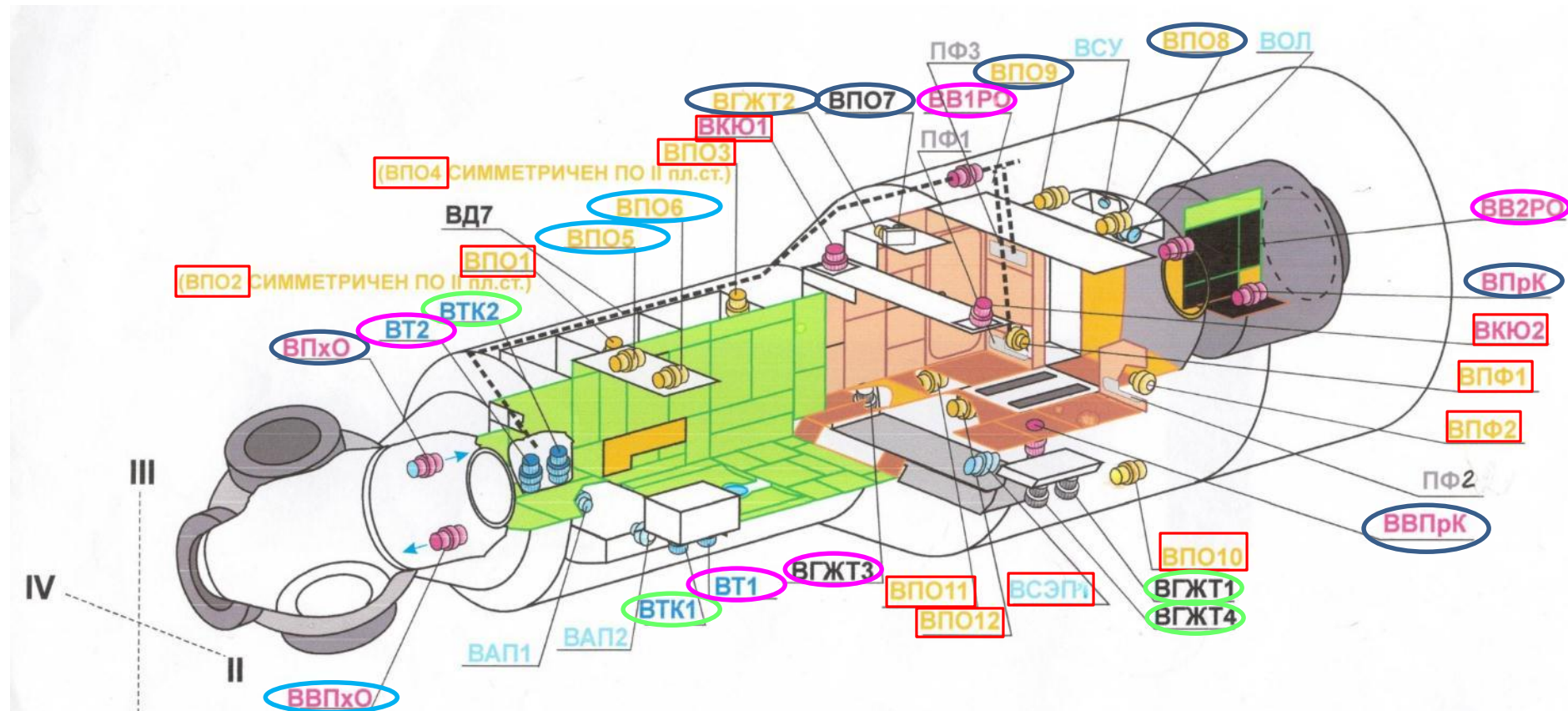
Before Cleaning



After Cleaning

(Courtesy
NASA)

Service Module Ventilation System Fans



- I = vibration isolation acoustic-lined duct
- = replaced with low-noise fan in week preceding Dec. 7, 2012 [7 fans]
- = replaced 11/2013 [4 fans]
- = replaced 12/2013 [5 fans]
- = replaced by 7/2014 [3 fans – but Nikimash not RSC-E fans]

Noise Controlled



- Acoustic treatments added to wall surfaces
- Noise enclosure was added to CO2 removal hardware (the “Vozdukh”)
- Inlet and outlet mufflers, vibration isolators, and acoustic wraps added to ventilation system fans
- Air conditioner compressor and fluid lines covered and new closeout panels were developed



(Photos courtesy of NASA)

Noise Controlled



(Photos courtesy of NASA)

Noise Controlled with Personal Hearing Protection



a) Disposable foam plug

- Attenuate high frequencies more than low frequency

b) Custom fitted ear plug (musician's ear plug)

- 15-25 dB flat attenuation

c) Custom fitted silicon ear monitors

- Attenuate noise while delivering high fidelity sound for On Orbit Hearing Assessment
- Noise protection while using exercise equipment

d) Active noise reduction headsets

- Attenuates more low frequencies



(Allen, Danielson, Allen, 2016)

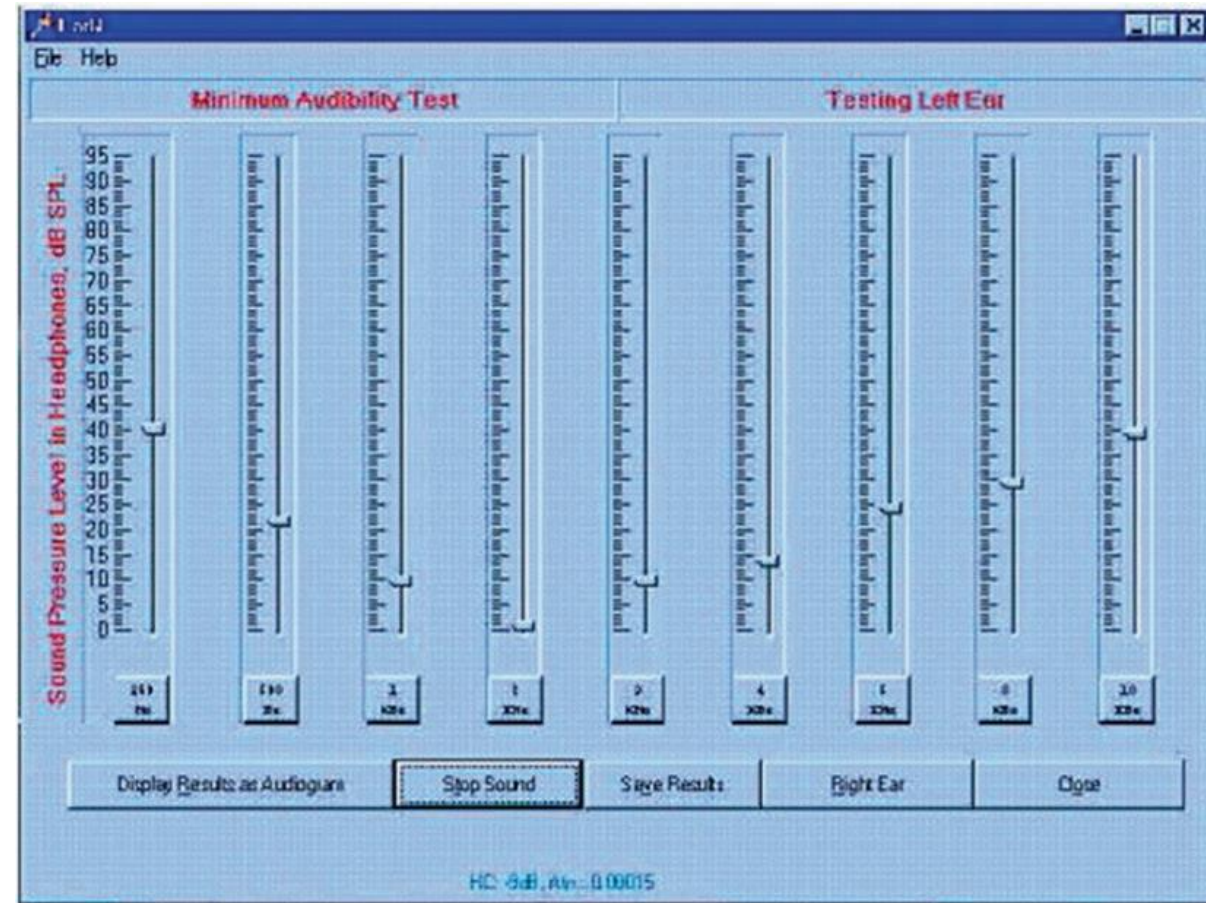
Spaceflight-Related Hearing Loss



On Orbit Hearing Assessment (OOHA)



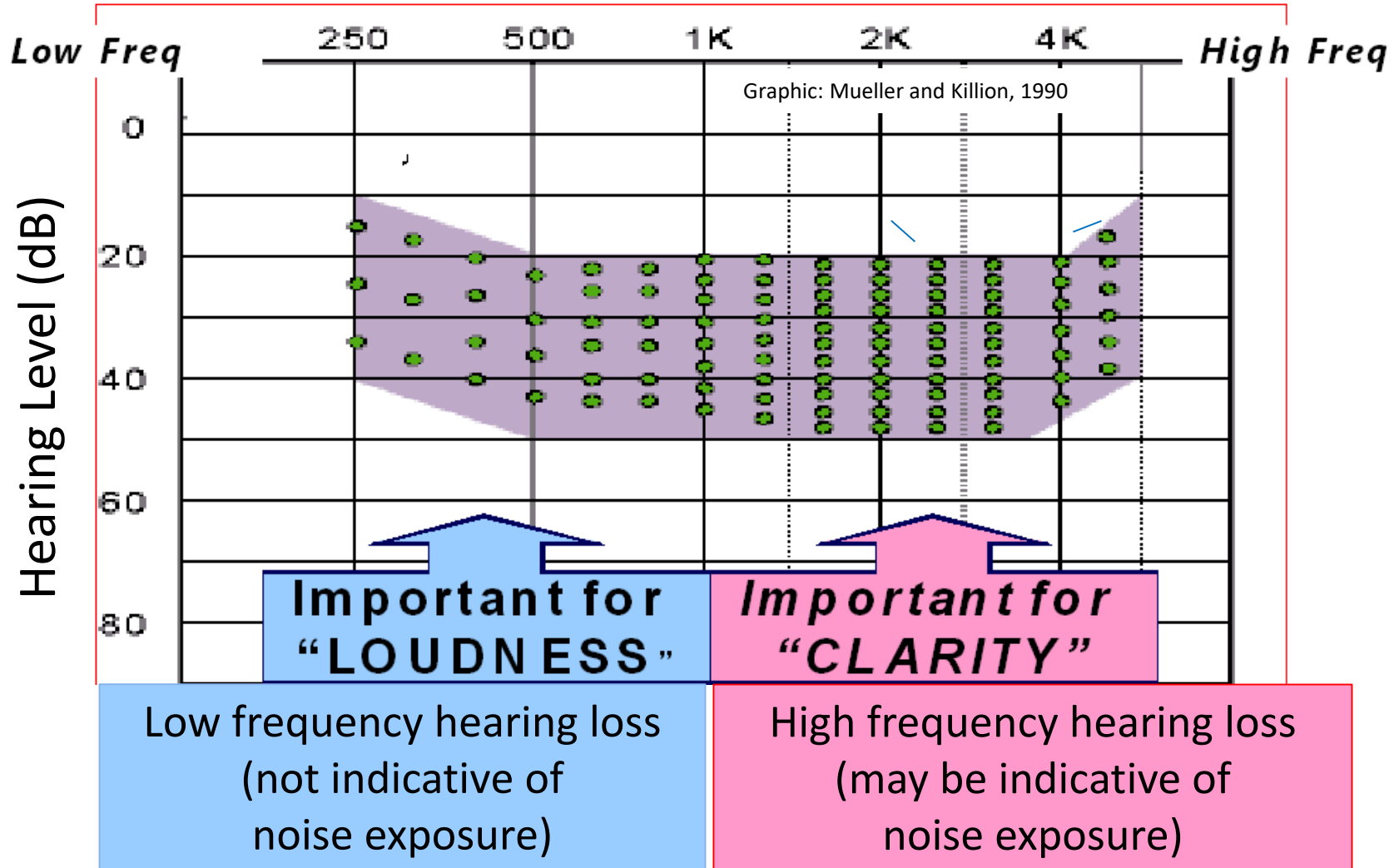
Sound Pressure Level dB SPL



Frequency

(Allen, Danielson, Allen, 2016)

Relating Hearing Sensitivity to Audibility Index (Using Conventional Audiogram)



Retrospective Analysis of On-Orbit Hearing Assessments (OOHAs)



Preliminary findings from OOHA data from USOS crew members (N= 75), ISS Expeditions 2-50 (264 OOHAs)

- **Low incidence of high frequency hearing threshold shifts during mission**
 - Averaging 2000, 3000, 4000 Hz (per OSHA and NASA Flight Crew criteria)
- **Higher incidence of low frequency hearing threshold shifts during mission**
 - Averaging 250 and 500 Hz (criteria used by JSC audiologist after identifying 5X more shifts in low frequencies than seen in high frequencies)
 - Possible reasons: ambient noise levels in ISS, hardware issues, or stiffness-related changes (in middle ear or cochlea)
- **Comprehensive analysis now underway**
- **Analyzing inflight OOHA shifts in comparison with conventional audiometric results from ground testing**

Reflections On ISS Noise



Reflections On ISS Noise



- **“It’s not all evil”**
 - There are pleasant aspects to the noise on ISS
 - Modification to airflow noticed and worrying
- **Become attuned to pump/fan noise**
 - “It’s the respiration of the organism that keeps you alive.”
- **“Similar to being on a sailboat in the wind”**
 - Does not take much wind before you can’t hear a crew mate $\frac{1}{2}$ a boat length away
 - Need to really raise voice to communicate across a module
 - Exacerbated by language and positional change
- **Becomes fatiguing for some crew members**
 - Some are more negatively impacted than others
 - May not realize it until in a quiet refuge
- **Caution alarms and warning tones**
 - Worry whether or not we will hear these alerts

Michael Barratt, M.D.



ISS019E009491

Reflections On ISS Noise



Kate Rubins, Ph.D.



Reflections On ISS Noise



- **Hearing/understanding a crew member at distance/around corners is difficult**
- **Constancy of noise is a stressor**
 - Fatiguing
 - Potential link to headaches
- **The quiet of crew quarters, particularly with door closed, was a relief.**
 - But even here there is constant noise
- **Would be great to have a place that is *truly quiet***



Crew Quarters



Special Thanks To:



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Johnson Space Center Astronaut Office
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Harvard Medical School

Questions?

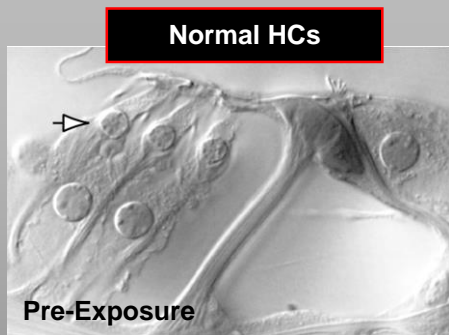


Backup

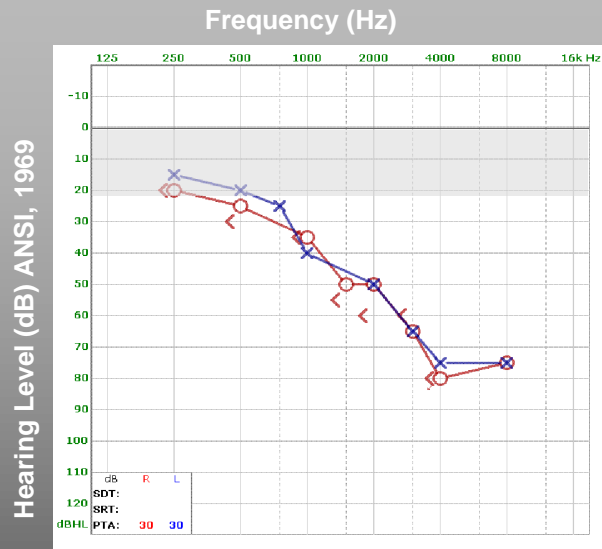


Hair cells as primary targets

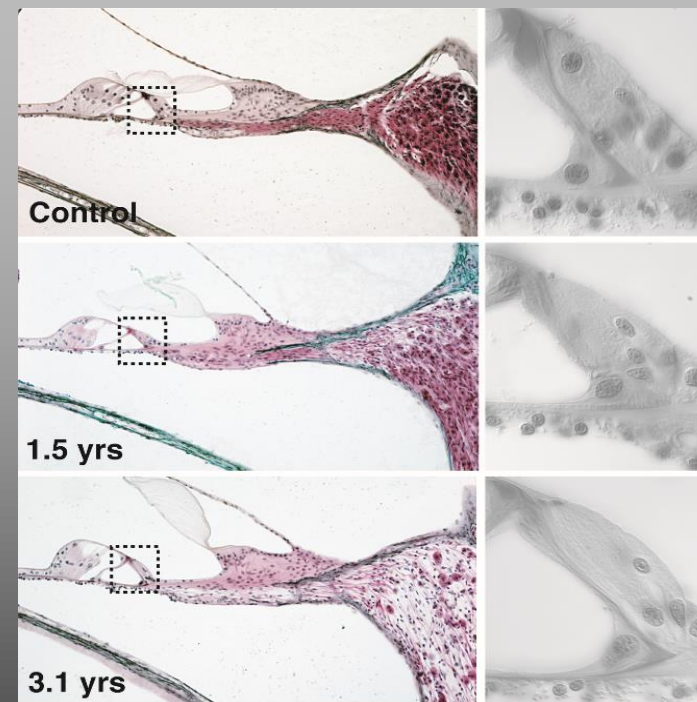
New view: Synapses are most vulnerable - importance of primary neural degeneration in acquired sensorineural hearing loss



Demonstrated vulnerability, rapid; easily linked to insult



Overt hearing loss; readily apparent consequences in the threshold audiogram



Loss is delayed in onset, protracted in time course relative to sensory cells