Aircrew Multi-Axis Vibration Exposures During Operation of the Blackhawk UH-60L Helicopter

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Background

- Military aircrews continue to report back discomfort, pain, and injury associated with flying rotary-wing aircraft.
- The Defense Centers for Public Health – Aberdeen (DCPH-A) and USAF are collaborating on a project to expand limited data on aircrew operational vibration exposure.
- The project is funded by the National Defense Center for Energy and Environment, Safety & Occupational Health Focus Group.
- It focuses on four platforms in addition to an initial study conducted on the HH-60M and UH-72.
- This presentation focuses on the UH-60L Blackhawk.

Objectives

Characterize and assess aircrew vibration exposure aboard the UH-60L.

- Investigate multi-axis acceleration spectra for targeted flight test conditions.
- Apply MIL-STD 1472/ACGIH (ISO 2631-1) to assess comfort and health risk.
- Conduct an aircrew survey regarding discomfort, vibration, and equipment.
- Document data in the AFRL Collaborative Biomechanics Data Network (CBDN).


Photo by Staff Sgt. Bethany Rizor

Methods – Data Collection Unit

- Remote Vibration Environment Recorder (REVER)
- Portable and Battery-operated
- Four systems required for flight test

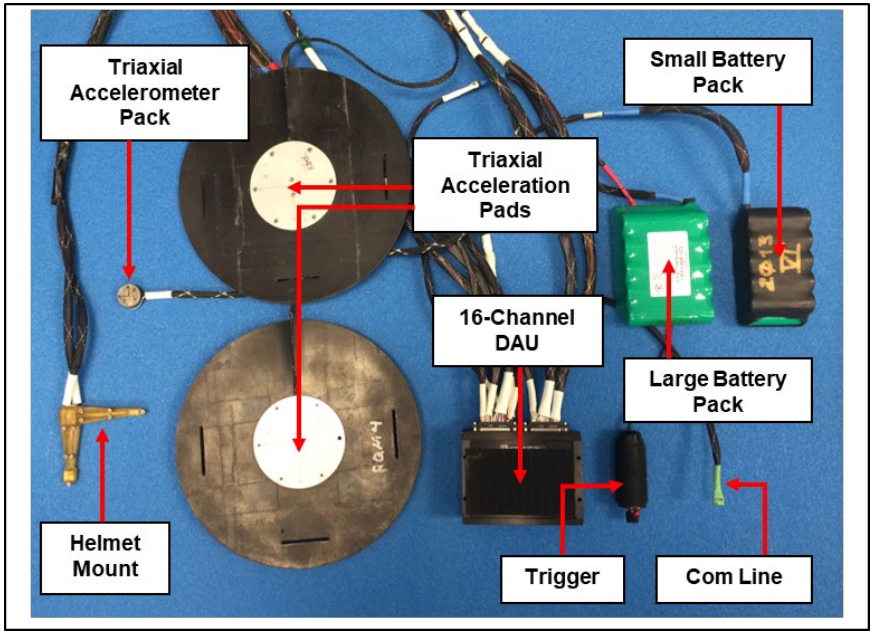


Photo by AFRL - Suzanne Smith

Methods - Seat Locations

Station	Measurement Site	Sensor Type
Pilot (right cockpit seat)	Seat Base	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
	Helmet	Six-Axis Helmet Mount
Crew Chief/Flight Engineer (mid cabin, side-facing right seat)	Floor beneath Seat	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
Crew Chief/Flight Engineer (mid cabin, side-facing left seat)	Floor beneath Seat	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
Crew Member (aft cabin, rear-facing right seat)	Floor beneath Seat	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
Crew Member (aft cabin, rear-facing left seat)	Floor beneath Seat	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad

Methods - Vest and Helmet Setup

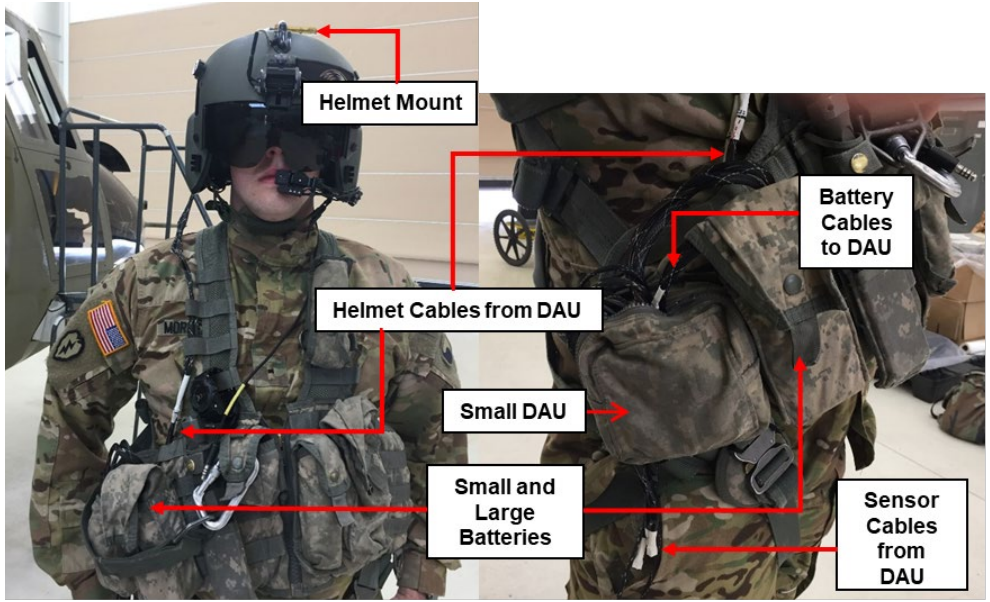
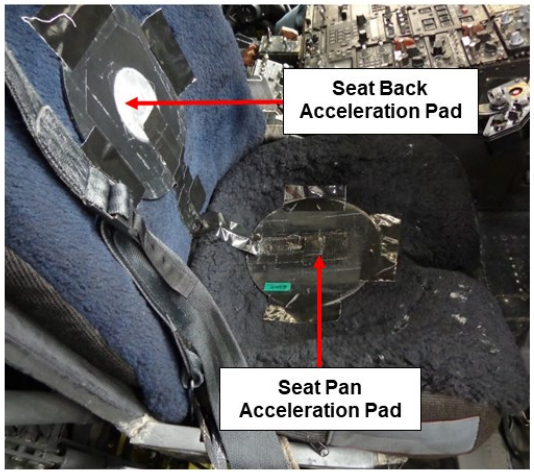
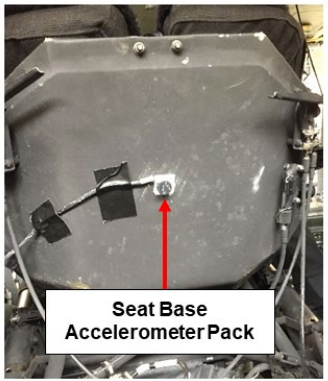


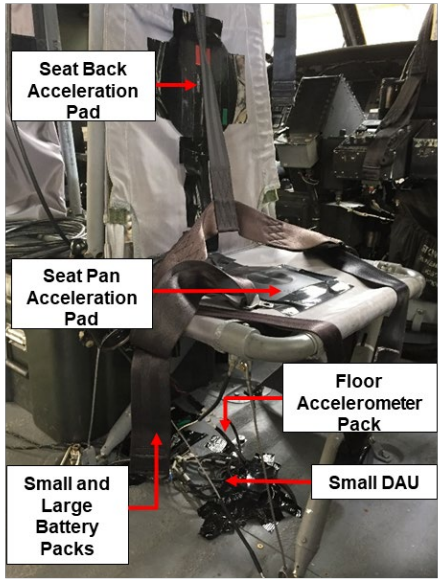
Photo by DCPH-A, Steven Chervak

Methods - Crew Seat Setup





Pilot Seat (Cockpit)



Crew Chief Seat
(Mid Cabin)

Photo by DCPH-A, Steven Chervak

Methods - Rear Seat Setup

(Note: Actual measurements taken at rear-facing seats)

Photo by DCPH-A, Steven Chervak

Methods – Test Conditions

- Flight Test Conditions
  - Per Task
  - Multiple Records
- Data Collection
  - Acceleration time histories collected for 20 sec. for each condition upon trigger activation

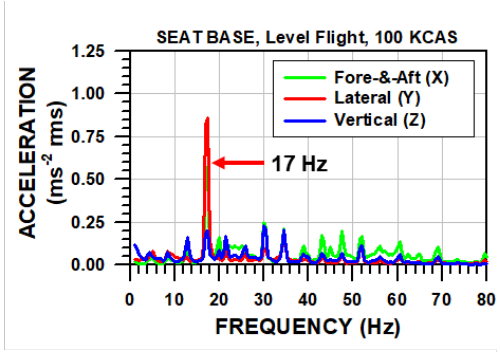
FLIGHT TEST CARD			
AC/#:	LOCATION/DATE:		
PI:	CP:	CC:	
Other:			
Flight #:	Station:		
CONDITION (*Multiple Test Records Desired)	ALT (ft MSL)	A/S (KCAS)	COMMENTS (Wind, Day, Night, etc.)
TASK 1024 Before Starting Through Before Leaving Helo Checks			
A. Engine Idle	0	0	
Record #:			
B. Ground Flight 100%	0	0	
Record #:			
TASK 1040 Perform VMC Takeoff			
C. Takeoff Normal		A/R	
Record #:			
D. Takeoff Vertical			
Record#:			
E. Takeoff Minimum Power			
Record#:			
TASK 1038 Perform Hovering Flight			
F. Hovering Stationary IGE*	3	0	
Record#:			
G. Hovering Taxi IGE*	3	0	
Record #:			
H. Hover OGE*	50<10K	0	
Record #:			
I. Transverse Flow*			
Record #:			
J. Landing	0	0	
TASK 1052 Perform VMC Flight Maneuvers			
K. Climb	<10K	65-80	
Record #:			
L. Level Flight*	<10K	80	
Record#:			
M. Level Flight*	<10K	100	
Record#:			
N. Level Flight*	<10K	120	
Record #:			
N2. Level Flight*	<10K	145	
Record #:			
O. Std Rate Turn	<10K	≤120	
Record #:			

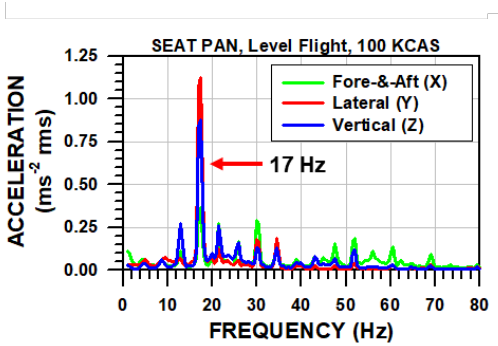
FLIGHT TEST CARD			
AC/#:	LOCATION/DATE:		
PI:	CP:	CC:	
Other:			
Flight #:	Station:		
CONDITION (*Multiple Test Records Desired)	ALT (ft MSL)	A/S (KCAS)	COMMENTS (Wind, Day, Night, etc.)
TASK 1024 Before Starting Through Before Leaving Helo Checks			
P. Steep Rate Turn	<10K	≤120	
Record#:			
Q. Descent		≤120	
Record #:			
R. AVCS Off	<10K	≤120	
Record #:			
TASK 1058 Perform VMC Approach			
S. Normal Approach to OGE Hover*	>50	≤120-0	8-10°
Record #:			
T. Steep Approach to OGE Hover*	>50	≤120-0	>10°
Record#:			
U. Normal Approach to IGE Hover*	3	≤120-0	
Record#:			
V. Steep Approach to IGE Hover*	3	≤120-0	
Record#:			
TASK 2026 Perform Terrain Flight			
W. NOE*	0-25	≤120	
Record #:			

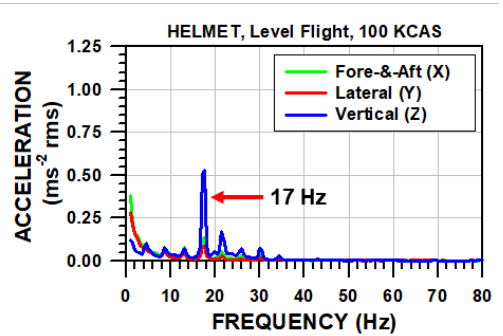
Methods – Data Processing

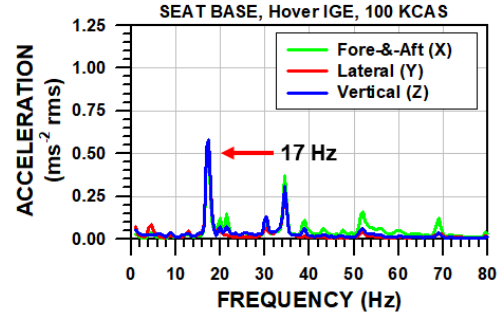
- Unweighted Acceleration Spectra (1–150 Hz)
  - Identify the frequency location/magnitude of major peaks.
  - PRF: Propeller Rotation Frequency
  - BPF: Blade Passage Frequency
- Weighted Overall Accelerations (1–80 Hz, ISO 2631-1)
  - Assess the comfort reaction and health risk.
  - pVTV: point vibration total value (vector sum of overall accelerations for three directions at seat pan and seat back)
  - oVTV: overall vibration total value (vector sum of pan and back pVTVs)
  - Estimate allowable exposure duration associated with no health risk

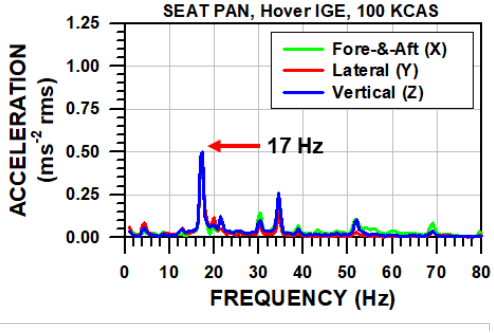
Results – Unweighted Acceleration Spectra

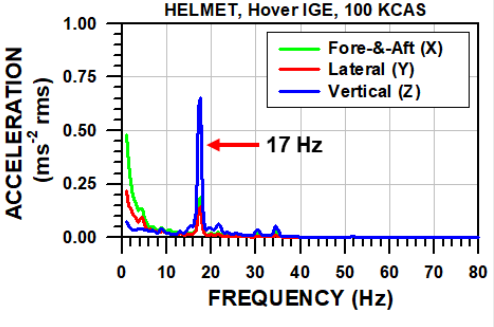




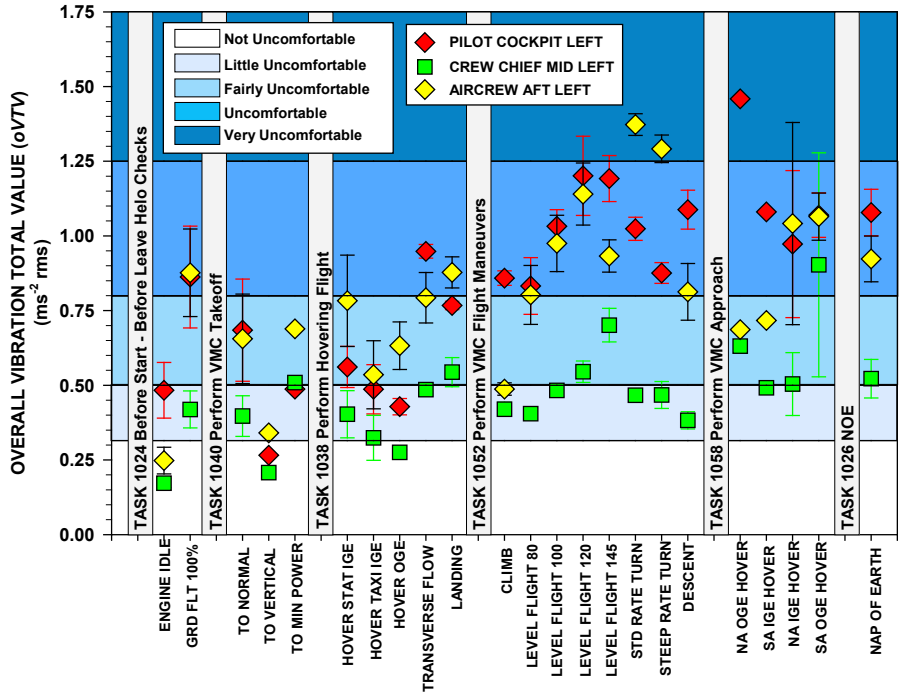




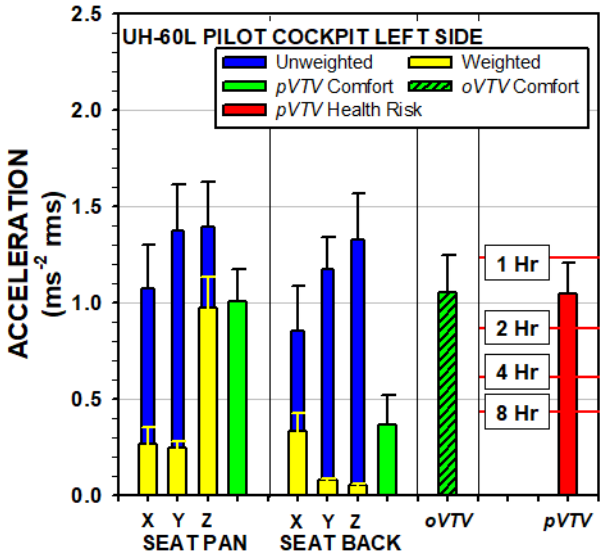


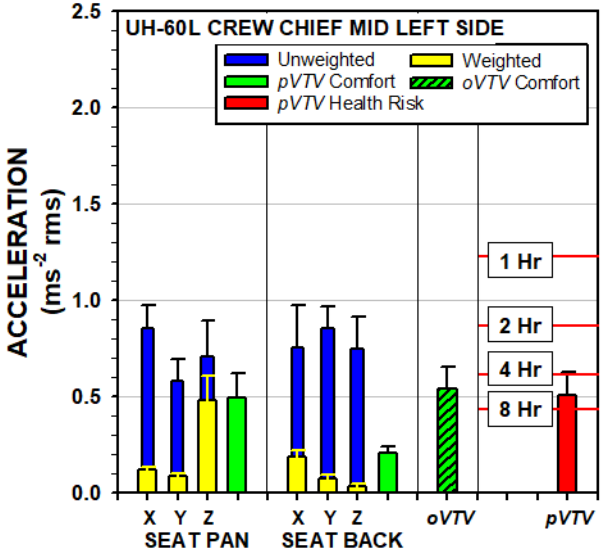


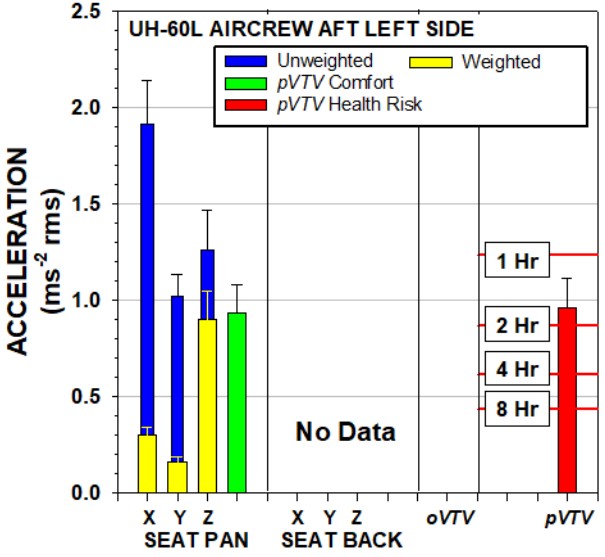
Results – Comfort Reactions (ISO 2631-1)



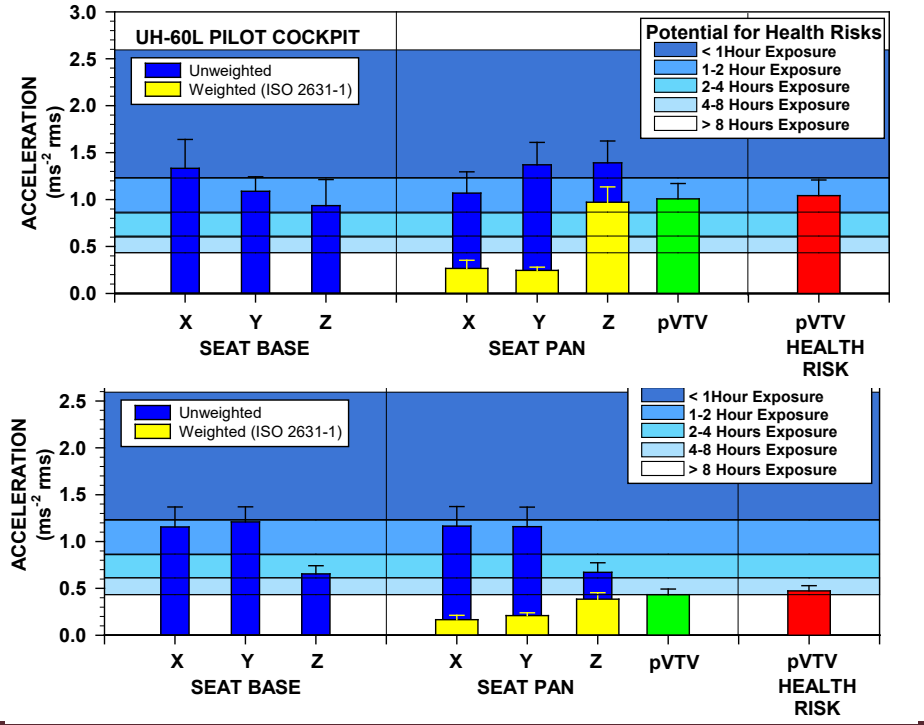
Results – Unweighted/Weighted Overall Acceleration



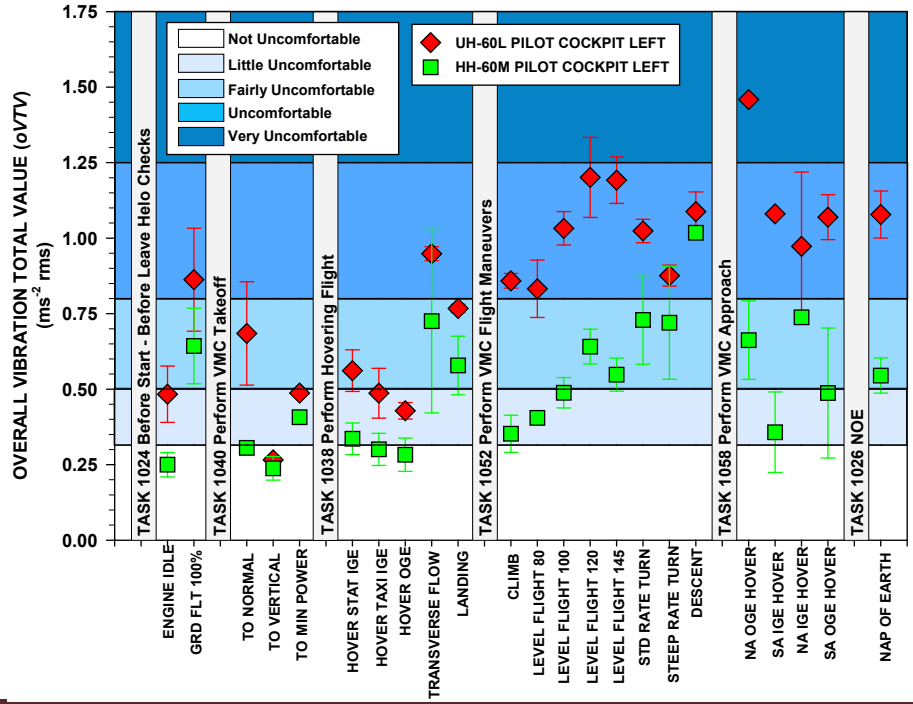




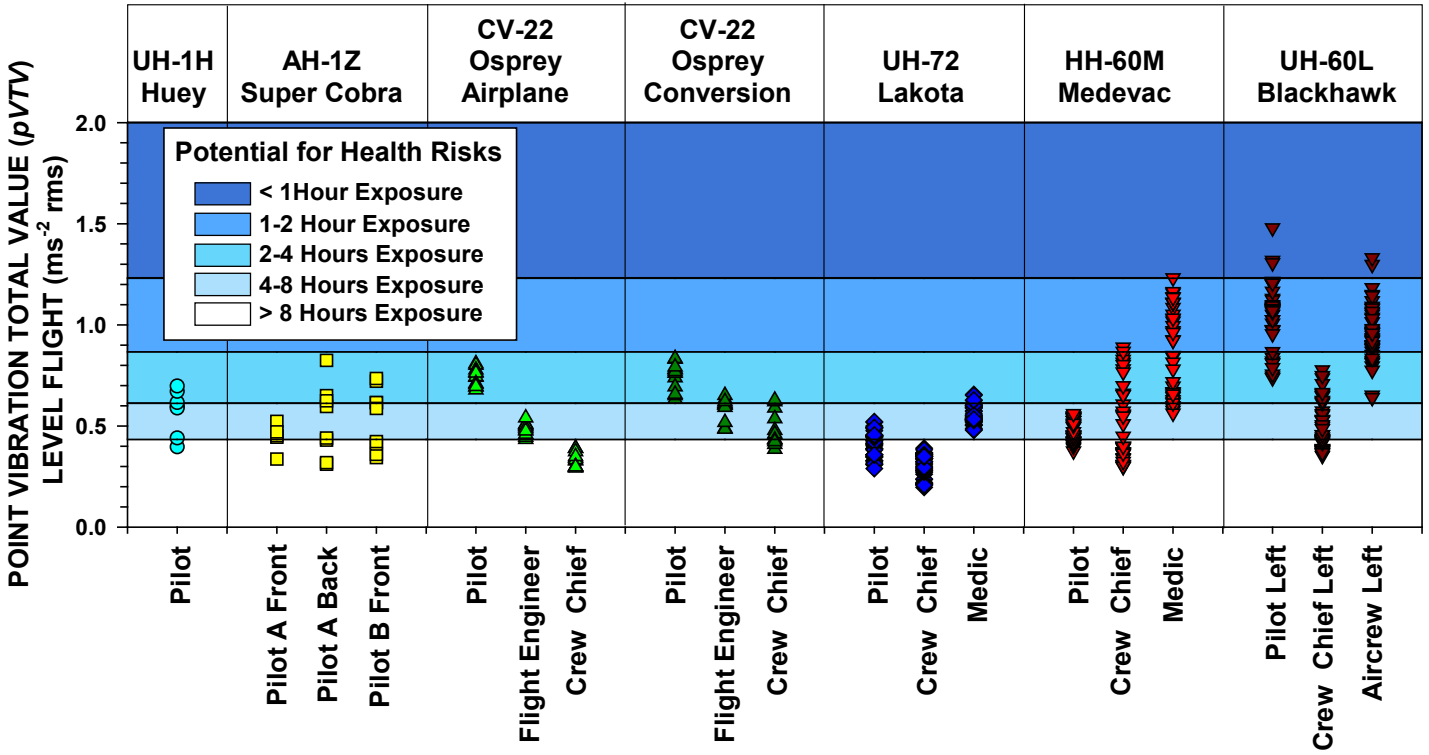
Results – Blackhawk Comparison



Results – Blackhawk Comparison (Comfort)



Results – Aircraft Level Flight Comparison



Conclusions

- Aircrew are exposed to significant higher-frequency multi-axis vibration (above 10 Hz).
- The assessment shows aircrew comfort and potential for health risks can occur in as little as 1-2 hours due to exposures over current recognized threshold limits (ACGIH, MIL-STD).
- Active aircraft vibration mitigation technologies can sufficiently reduce this threat.
- The mechanism(s) by which vibration may affect aircrew physiology and health risk are still not clear and further research is needed to improving mitigation concepts.
- The vibration data collected will be used to establish appropriate criteria for developing effective mitigation concepts through modeling.

Acknowledgement

DCPH-A and AFRL would like to thank the NDCEE for their support