The F/A-18 Program Office

Management of Environment, Safety, and Occupational Health Challenges

F/A-18E/F

E/A-18G

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Report Documentation Page

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Background

- Program Manager Air (PMA)265 of Naval Air Systems Command (NAVAIR) manages the variants and subsystems of the F/A-18 aircraft, including the EA-18G Growler
- PMA265 acknowledges their responsibility to assure sustained environmental readiness
  - Promotes a dedicated environment, safety, and occupational health (ESOH) integrated product team – The Green Hornet Team (GHT)
  - Invests in processes and technologies to minimize ESOH risks, hazardous materials usage, and reduction in air and noise emissions
- PMA265 recognized for their ESOH excellence in weapon system acquisition
  - Recipient of four consecutive Chief of Naval Operations Environmental Awards (Fiscal Year (FY) 2001, 2003, 2005, & 2007)
  - Recipient of FY 2003 Secretary of Navy Environmental Award
  - Honorable Mention in FY 2003 Secretary of Defense Environmental Award

Green Hornet Team

- Multi-Disciplinary and interactive team of Government and industry subject matter experts whose charter is to:
  - Assess, advise, and communicate potential ESOH concerns or risks
  - Minimize potential ESOH impacts associated with the acquisition system life-cycle process
  - Assure sustainment of F/A-18 and EA-18G mission requirements and protection of environmental and personnel resources
  - Participate in ESOH engineering solutions and technologies
    - Trapped Vortex Combustor (TVC) – Low emission and reduced fuel consumption
    - **Non-Chromated plating and primers**
    - Dedicated cockpit pre-cooling switches – Eliminate hypoxic conditions to crew
    - HFC-125 (non-ozone depleting substance) in engine fire suppression system

PMA265 Green Hornet Team

- PMA265 ESOH Manager
- PMA265 System Safety Engineers
- NAVAIR Materials
- NAVAIR Power & Propulsion
- NAVAIR Research & Engineering
- Boeing Corporation
- General Electric Aircraft Engines
- Northrop Grumman Corporation
- Raytheon
- Booz Allen Hamilton

ESOH Sustainment Concerns

- Air quality
  - Attainment/non-attainment at United States Navy (USN) installations
    - Particulate Matter, Nitrogen Oxides, Volatile Organic Compounds
    - National Emission Standards for Hazardous Air Pollutants
- Hazardous materials (HAZMAT) usage
  - **Hexavalent chromium,** cadmium, thermal barrier coating (a low level radioactive waste)
  - Approval of HAZMAT on USN installation's HAZMAT Authorized Usage Lists
  - Feasibility of alternative implementing materials and processes
  - European Union regulatory compliance
- Near- and far-field noise levels
  - Community noise
  - Personnel exposure to high levels of noise on flight line and deck
  - CONUS & OCONUS basing constraints

Hexavalent Chromium

- **USD (AT&L) MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS - SUBJECT: Minimizing the Use of Hexavalent Chromium *(Cr)* of 8 April 2009**
- **Requires Military Departments to:**
  - Invest in appropriate research and development on substitutes.
  - Ensure testing and qualification procedures are funded and conducted to qualify technically and economically suitable substitute materials.
  - Approve the use of alternatives where they can perform adequately.
  - Document the system-specific $Cr^{6}+$ risks and efforts to qualify less toxic alternatives in the Programmatic Environment, Safety, and Occupational Health Evaluation for the system.
  - Share knowledge derived from research, development, testing and evaluations (RDT&E) and actual experiences with qualified alternatives.

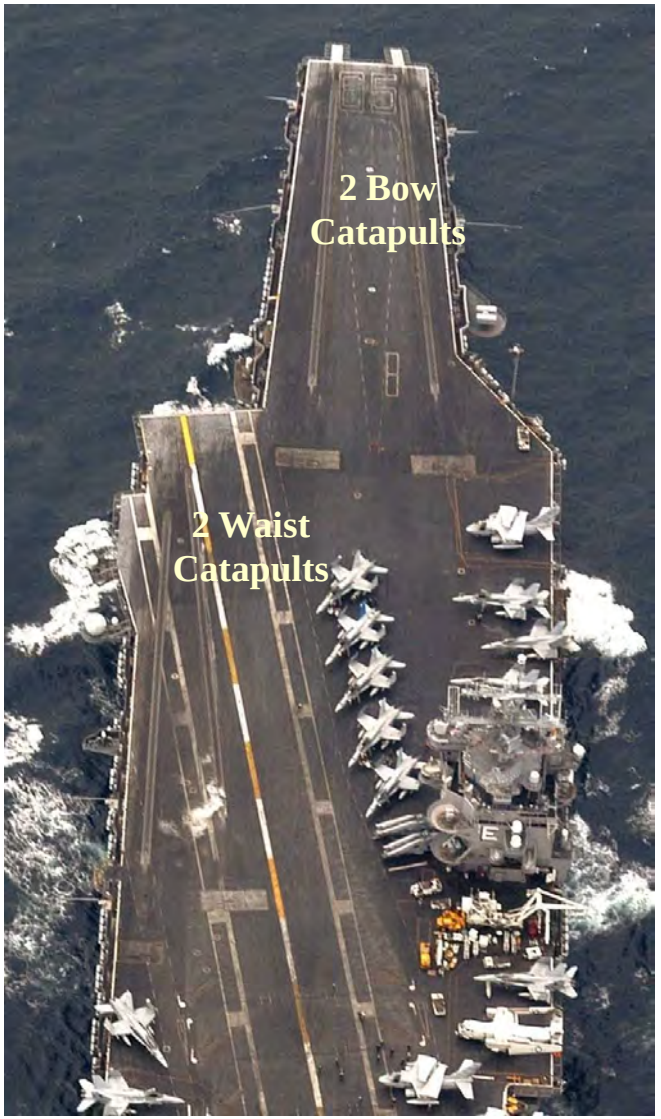
- **Additionally requires the Program Executive Office (PEO) or equivalent level, in coordination with the Military Department's Corrosion Control and Prevention Executive (CCPE), to certify there is no acceptable alternative to the use of $Cr^{6}+$ on a new system.**

Military Jet Aircraft Noise

A Case Study in ESOH Risk

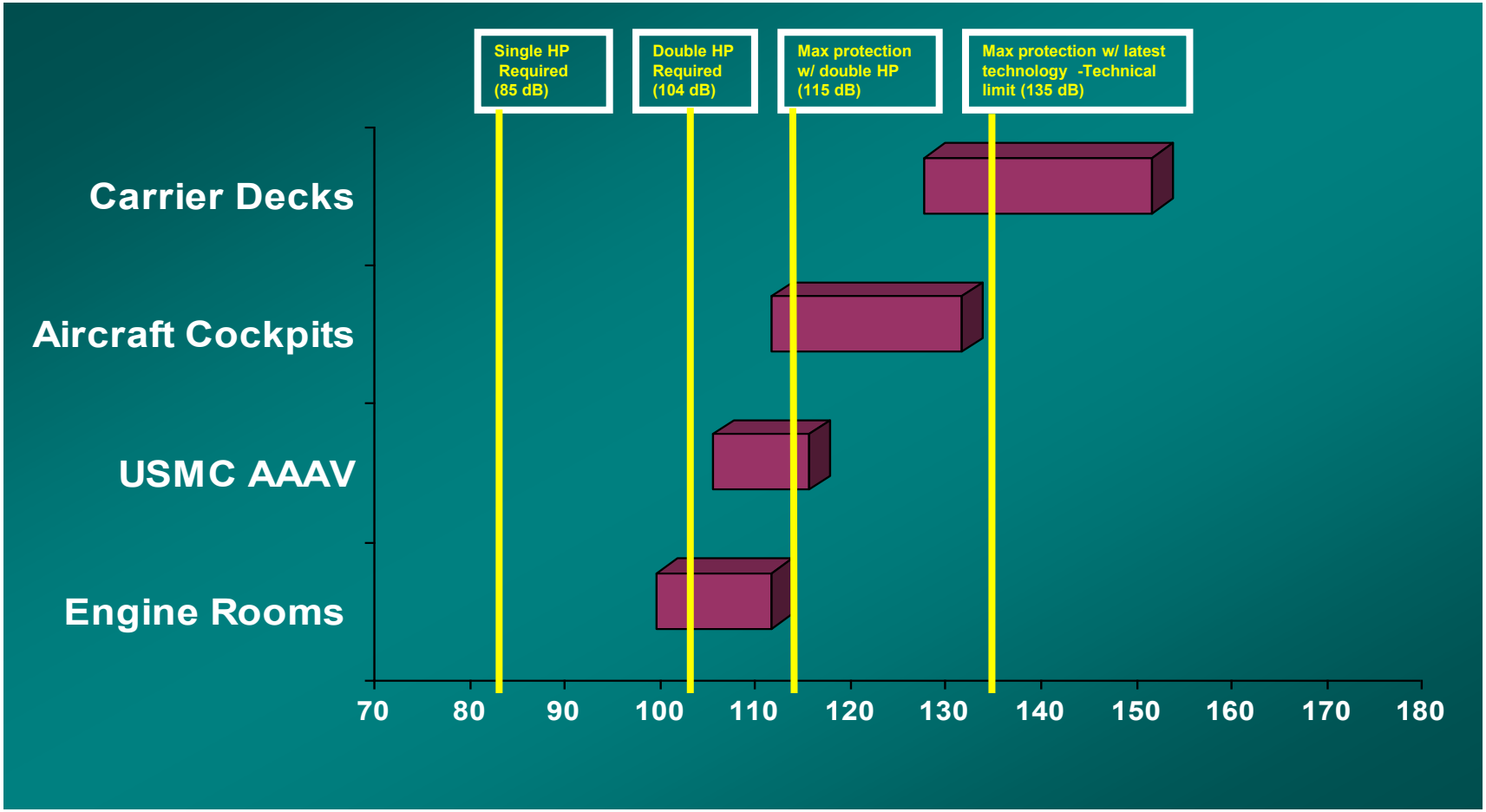
CVN – Centerpiece of Naval Aviation

- Up to **5,680** crew
- About **85** tactical aircraft
- **4** launch catapults with almost concurrent operation
- **200** launches/recoveries per deck personnel per 12-hour duty shift



Flight Deck Personnel Exposed to Brutal Acoustic Loads

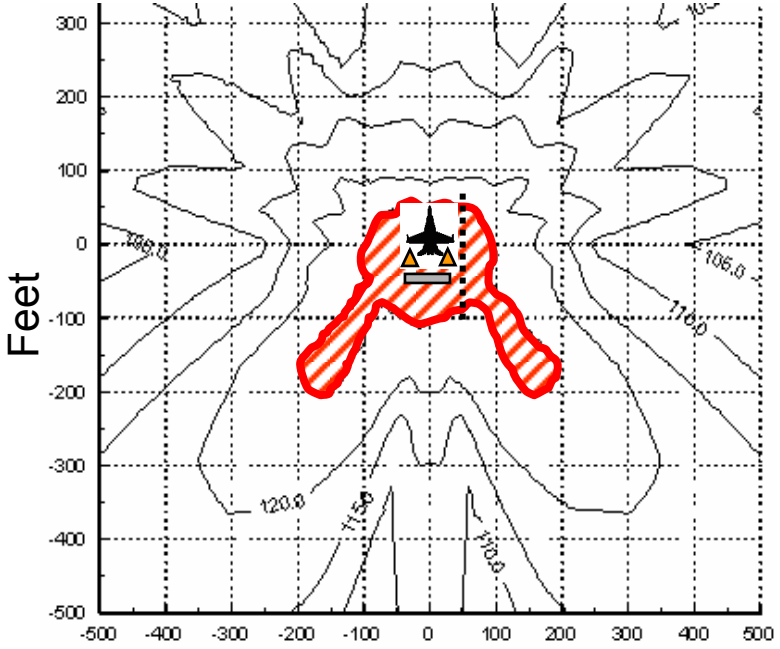
DASN (Safety): "carrier deck *the noisiest* USN\USMC environment"

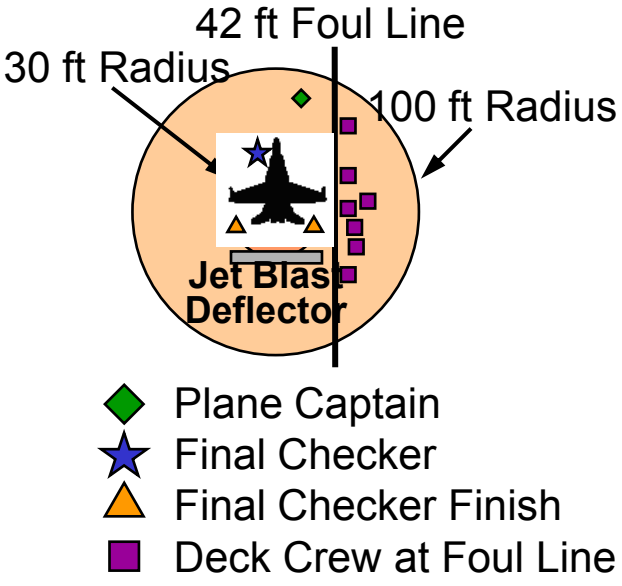


Noise Level decibels (dB) A-weighted (dBA)

F/A-18C/D Noise Contours & Carrier Deck Launch Positions

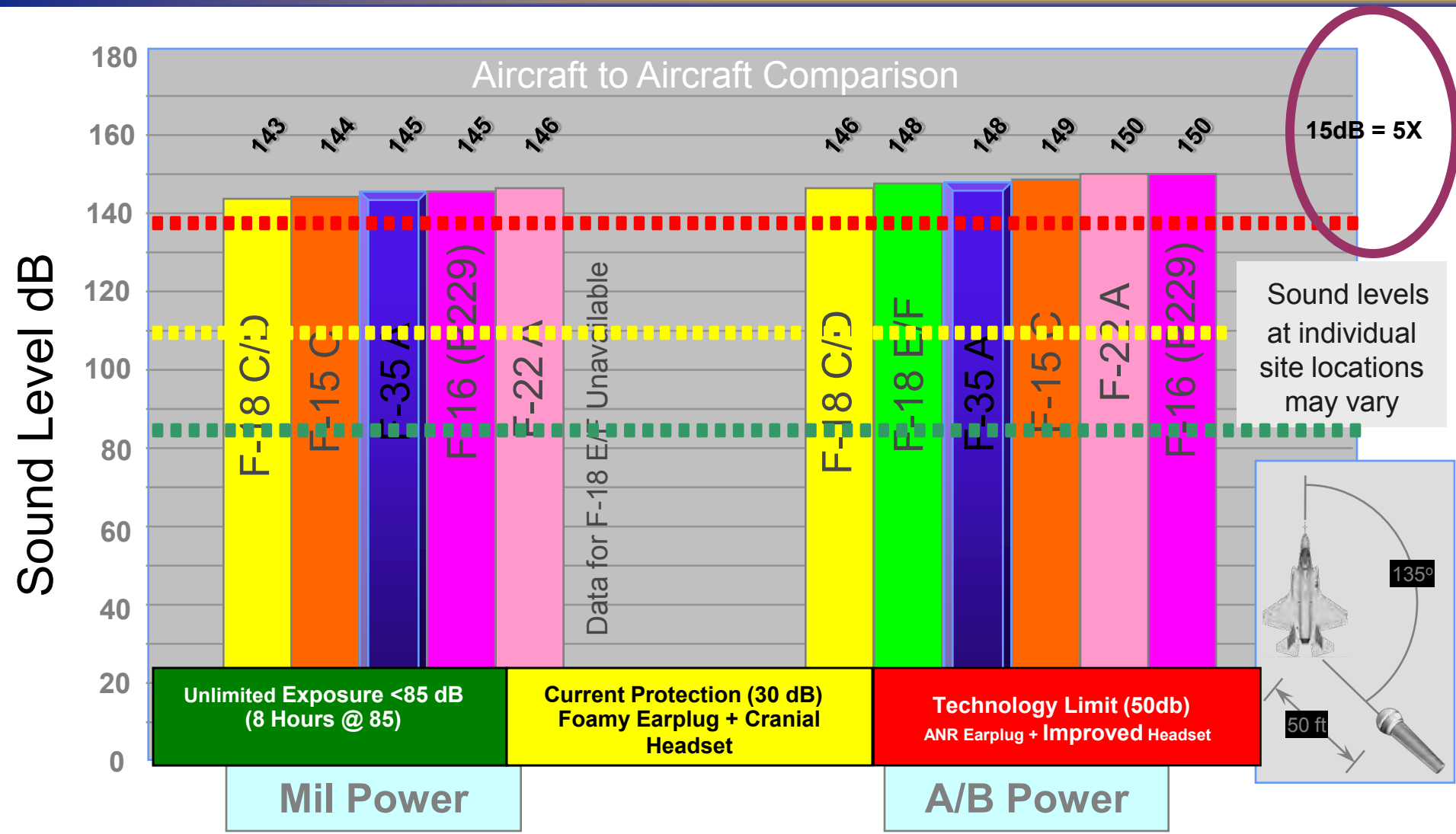
- Single catapult launch data; no data available for concurrent cat launches
- Personnel in red contour area exceed total daily exposure in approximately 1 launch
- Multiple catapult launches undoubtedly more severe
- Concurrent launches from all 4 catapults expose personnel to peak acoustic loads





Maintenance & Operations Personnel Acoustics

Measured Worst Case Aircraft Sound Levels - @ 50 ft *



*Joint Communications Release, JSF Program Office & Lockheed Martin, Subject: F-35 Acoustics Based on Edwards AFB Acoustics Test, April 2009

DOD Noise Standards & Regulations

USN (& USAF) currently <u>not</u> compliant with the following standards:

- DoD Design Criteria Std., MIL-STD-1474D, Noise Limits, page 65, para 4.2.1, Aircraft Noise
- DoDI 6055.12, Hearing Conservation Program
- OPNAVINST 5100.23F, Navy Occupational Safety and Health Program Manual
- NAVMEDCOMINST 6260.5 Occupational Noise Control & Hearing Conservation
- AFOSH STD 48-19, Hazardous Noise Program
- AFOSH STD 161-20, Hearing Conservation Program
- OSHA 29 CFR, Occupational Noise Exposure
- 85 dBA, 8 hrs, 3 dB/doubling exchange rate (*USN until recently was under a 4 dB rate*)

USD 5 Aug 01 Memo, Dr. Gansler to ASN & ASAF: "I request you make investing in hearing protection a ***<u>top</u>*** (S&T) priority…and a Defense Technology Objective"

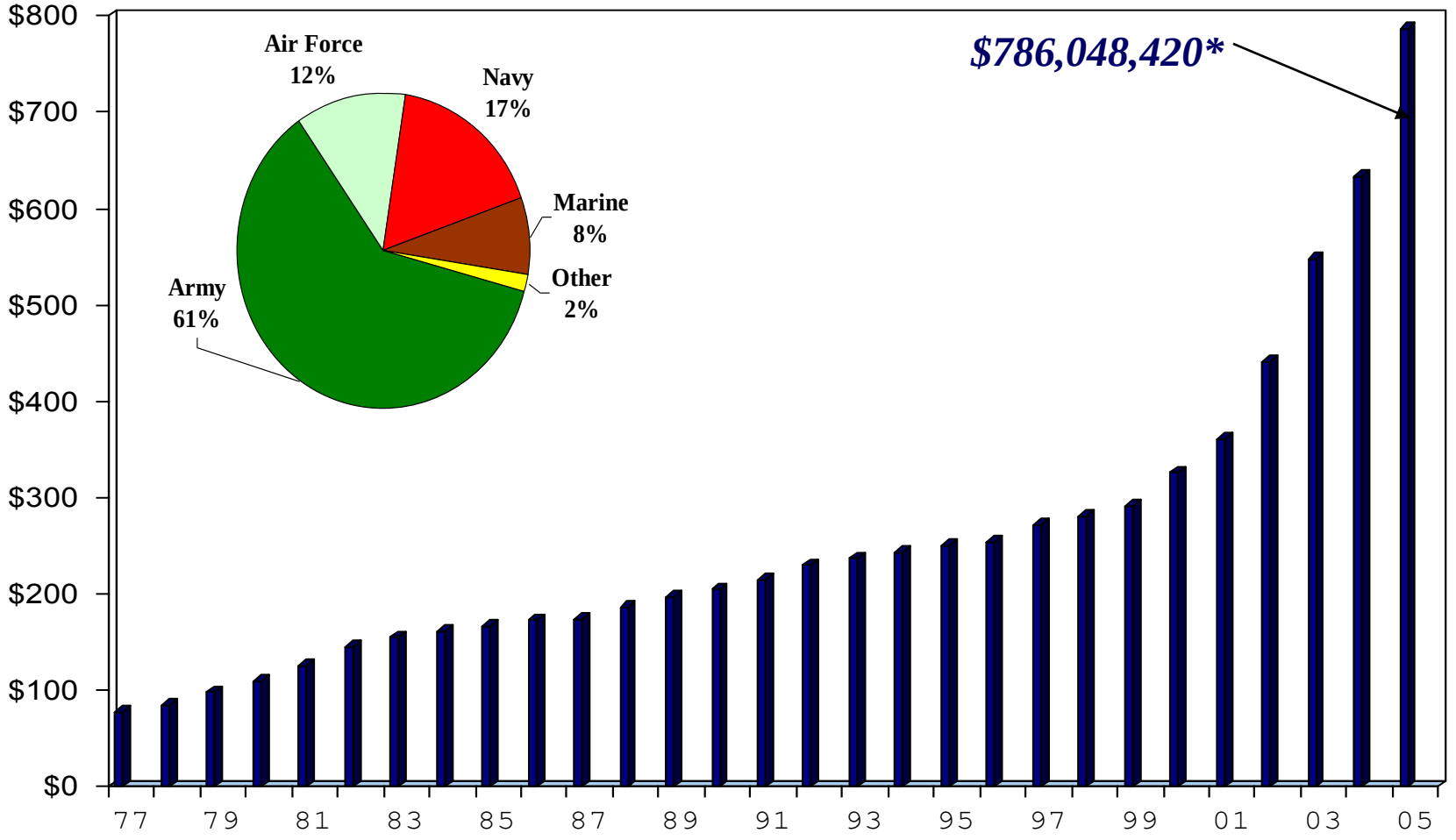
Allowable Noise Exposures*

Environments				Noise Level db	Safe Noise Level Duration Times				UNPROTECTED		RESULTING NOISE LEVEL WEARING 30 dB HEARING PROTECTION & SAFE EXPOSURE LIMIT		RESULTING NOISE LEVEL WEARING 43 dB HEARING PROTECTION & SAFE EXPOSURE LIMIT		RESULTING NOISE LEVEL WEARING 50 dB HEARING PROTECTION & SAFE EXPOSURE LIMIT	
					Unprotected	Cranial + Foam Inserts (+30db protection)	Improved Earcups + Hard Plugs (+43db protection)	Active Noise Reduction (+50db protection)								
					0	30	43	50	dB	min	dB	min	dB	min	dB	min
			150	151	Exceeded	7s	2m 22s	11m 54s	151	0.00	121	0.12	108	2.36	101	11.91
				148		14s	4m 44s	23m 49s	148	0.00	118	0.23	105	4.72	98	23.81
				145		28s	9m 27s	47m 37s	145	0.00	115	0.47	102	9.45	95	47.62
				142		56s	18m 54s	1h 35m 15s	142	0.00	112	0.94	99	18.90	92	95.24
				139		1m 53s	37m 48s	3h 10m 29s	139	0.00	109	1.88	96	37.80	89	190.49
				136		3m 45s	1h 15m 36s	6h 20m 59s	136	0.00	106	3.75	93	75.60	86	380.98
				133		7m 30s	2h 31m 11s	12h 41m 57s	133	0.01	103	7.50	90	151.19	83	761.95
		130		130	1s	15m	5h 2m 23s		130	0.01	100	15.00	87	302.38	80	SAFE
				127	2s	30m	10h 4m 46s		127	0.03	97	30.00	84	604.76	77	SAFE
				124	4s	1h			124	0.06	94	60.00	81	SAFE	74	SAFE
	120			121	7s	2h			121	0.12	91	120.00	78	SAFE	71	SAFE
				118	14s	4h			118	0.23	88	240.00	75	SAFE	68	SAFE
				115	28s	8h			115	0.47	85	480.00	72	SAFE	65	SAFE
				112	56s				112	0.94	82	SAFE	69	SAFE	62	SAFE
110				109	1m 53s				109	1.88	79	SAFE	66	SAFE	59	SAFE
				106	3m 45s				106	3.75	76	SAFE	63	SAFE	56	SAFE
				103	7m 30s				103	7.50	73	SAFE	60	SAFE	53	SAFE
				100	15m				100	15.00	70	SAFE	57	SAFE	50	SAFE
				97	30m				97	30.00	67	SAFE	54	SAFE	47	SAFE
				94	1h				94	60.00	64	SAFE	51	SAFE	44	SAFE
				91	2h				91	120.00	61	SAFE	48	SAFE	41	SAFE
				88	4h				88	240.00	58	SAFE	45	SAFE	38	SAFE
				85	8h				85	480.00	55	SAFE	42	SAFE	35	SAFE
				82	SAFE				82	SAFE	52	SAFE	39	SAFE	32	SAFE

Rotary/Prop Cockpit | Rotary/Prop Aircraft Flight Deck | Tactical Aircraft Cockpit | Exterior Tactical Aircraft Flight Deck Proximity

*American Conference on Governmental Industrial Hygienists (ACGIH) Threshold Limit Value®

Cost Of Hearing Loss For All Veterans 1977-2006 Total = $8,385,892,465*



*Department of Veterans Affairs is paying the bills for noise non-compliance

F/A-18E/F and EA-18G Noise Exposure Risk Acknowledgement

- Current personnel hearing protection devices are inadequate
  - Only operational measures offer near term solutions (e.g., moving carrier flight deck personnel away from jet exhaust)
  - New hearing protection devices offering better noise attenuation becoming available
  - Noise exposure will continue to be an issue for the user community even with the best hearing protective devices and engineering solutions
- Flight line/deck jet noise is a serious ESOH risk for the F/A-18E/F and EA-18G Programs
  - Acknowledgement of risk by Program Executive Office Tactical Aircraft Programs [PEO(T)] and Chief of Naval Air Forces (CNAF) in March 2008
  - PMA265 is participating in projects to minimize personnel exposure to jet noise levels above Occupational Safety and Health Administration and USN standards
  - PMA265 has committed to annually assess the viability of incorporating proven technologies into the F/A-18E/F and EA-18G

OCCUPATIONAL HEALTH & COMMUNITY NOISE ISSUES CANNOT BE IGNORED AND MUST BE ADDRESSED

Technology Challenge

- Problem of exhaust jet noise reduction has many aspects
  - Personnel safety
  - Community noise pollution
  - Aircraft signature & survivability
  - Engineering challenges
- Technology feasibility must proceed with caution and deliberation
  - Complexity and *also controversial* nature of the noise exposure problem
  - Current austere funding climate demands consensus with different agencies and pooling of ongoing noise reduction efforts
  - Tap into and mesh efforts with common objectives and leverage/synergize efforts
- The goal
  - Draw from basic research
  - Apply the lessons of that research
  - Test the concepts in real world operational environments
  - Achieve program transition

PMA265 Jet Noise Reduction Effort What/Why/When Capability Needed?

- Need
  - Effective means of reducing jet noise at the source (the engine)
  - No impact on military aircraft performance
- Why the Need
  - Jet noise imposes severe occupational safety and health risks to USN personnel
  - Hearing loss is identified too late
  - Cost of community jet noise continues to escalate
    - $38 million in damages paid by the USN caused by jet noise in Virginia Beach area
    - USN's potential liability in the Tidewater VA area - $350 million
    - $10 million in litigation costs for an outlying field in Eastern NC
    - Outlying field cost – exceed $300 million
- When Needed
  - Ideally yesterday…realistically within a couple of years if supported/funded
  - Only small incremental changes (3 dB) to fielded propulsion systems are possible
  - Major changes require substantial $$$ and significant time

Noise Reduction Initiatives

- Various DoD, academia, and industry research and development efforts
- Office of Naval Research (ONR)
  - Trailing Edge Chevrons
  - Micro Air Jets
  - Micro Water Jets
  - Power Resonance Tubes
- Boeing Beveled Angle Nozzle
- Florida State University Multiple Jet and Water Injection
- University of Mississippi Corrugated Jet Nozzle Seals
- Purdue University Aero-Acoustic Studies of Swirling Combustor Flows and Flames
- Pennsylvania State University Nonlinear Propagation Modeling
- General Electric (GE) Aircraft Engines (GEAE) Fluidic Injection and Mechanical Chevrons

The Proposed Solution

- Technology
  - Reduce jet noise at the source: chevrons on engine nozzle
  - Minor change in nozzle configuration; not major redesign
  - Compliments NAVAIR/Joint Strike Fighter hearing protection technology
- ONR Rapid Technology Transition (RTT) project
  - Transition viable technologies into the DoD Force within 24 months or less
  - Supportable business case (return of investment, improved capability, urgent need, technical maturity, company viability)
- Major goals/schedule by fiscal year:
  - FY09: System Development and optimization
  - FY10: Flight and jet blast deflector demonstration; functionality in afterburner
  - FY10: Manufacture/production cost analysis; System safety & long term durability testing

Senior Level Endorsements

- U.S. Fleet Forces: "…this specific RTT F/A-18 Jet Noise Reduction Initiative is not only prudent, it is necessary for future fleet readiness."
- Naval Safety Center: "…enthusiastically supports efforts by the acquisition community to develop weapons systems with reduced noise signatures and this specific RTT F/A-18 Jet Noise Reduction Initiative."
- Assistant Secretary of the Navy (Installations & Environment): "…Succeeding generations of aircraft with their higher noise levels have only made this problem worse. Engineering solutions that reduce aircraft noise are key to resolving this problem."
- Chief of Naval Air Forces (CNAF): "supports…this specific RTT F/A-18 Jet Noise Reduction Initiative.")

Chevrons On GE Commercial Engines

GE has successfully developed chevrons as a retrofit (CFM56-5B) and as baseline configuration for new engines (CF34) – certified and in revenue service.

A321/CFM56-5B

CF34-8C5 on CRJ-900

CF34-8E on ERJ 170

Flight Test with Chevrons on GE-90-115B

Chevrons Integrated With Exhaust Nozzle Seals

How Do Chevrons Work?

- Generate vorticity which mixes the two streams faster
  - Reduces peak velocity faster and reduces noise
- Alters and weakens shock cell structure to reduce broadband shock noise

Prototype Chevrons being tested on the F/A-18 engine by ONR/GE at Naval Air Warfare Center Aircraft Division, Lakehurst, 9/07

Why Chevrons For The F/A-18?

- GE has successfully developed chevrons as a retrofit and as a baseline configuration for new engines – commercial aircraft
  - F/A-18E/F F414 engine would required a forward fit approach
- Evolutionary, vice revolutionary
- Design approach allows for rapid technology insertion
- Chevrons provide the best trade between noise and system impact of any noise reduction feature
  - Performance
  - Weight
  - Cost
  - Life
- Chevrons may provide other benefits to the weapon system
  - Decreased infrared signature

THIS IS A NEW APPLICATION OF A PROVEN TECHNOLOGY

How Much Does This Project Cost?

- Research and Development
  - Initial proof of the technology functionality
  - **$2.525** Million
- PMA265 (Program Office)
  - Validation and test that the technology works in the system
  - **$3.300** Million
- Integration of the technology into the F/A-18s
  - Retrofit/back-fit solution
  - **$97.989** Million
- Total Cost
  - **$103.813** Million

F/A-18 Jet Noise Reduction Summary

- Need for jet noise reduction at the source – the engine – is clear, immediate and compelling
  - Noise induced hearing loss risk to our service members
  - Community jet noise issues
- Naval Leadership and the Fleet demand a solution
- Assistant Secretary of Navy (Research, Development, & Acquisition) direction mandates that PEO(T) "develop solutions to reduce noise for current and next generation naval systems . . ."
- Our RTT F/A-18 Jet Noise Reduction Program – chevrons – seeks to demonstrate and transition this affordable technology; Now is the time to strike
  - Jet noise goal of up to 3 dBA reduction
  - Technology is transferable to other engines/nozzles
  - Future systems may benefit from this design solution

"We can and must do a better job of protecting those men and women who routinely sacrifice so much for this country."

T. A. Rollow, DASN(S)