

TOP KNIFE FIGHTER SURGEON COURSE

173 Fighter Wing
Kingsley Field Oregon

RSV-1B1

AEROMEDICAL AND PHYSIOLOGIC
ASPECTS OF ACCELERATION

Criterion Referenced Objectives

- Define G-tolerance, how it applies to aircraft in flight, and how it impacts the flyer
- Examine the effect of G on the cardiovascular system
- Examine the effect of G on the respiratory system
- Recognize the strategies for increasing G-tolerance and preventing G-LOC

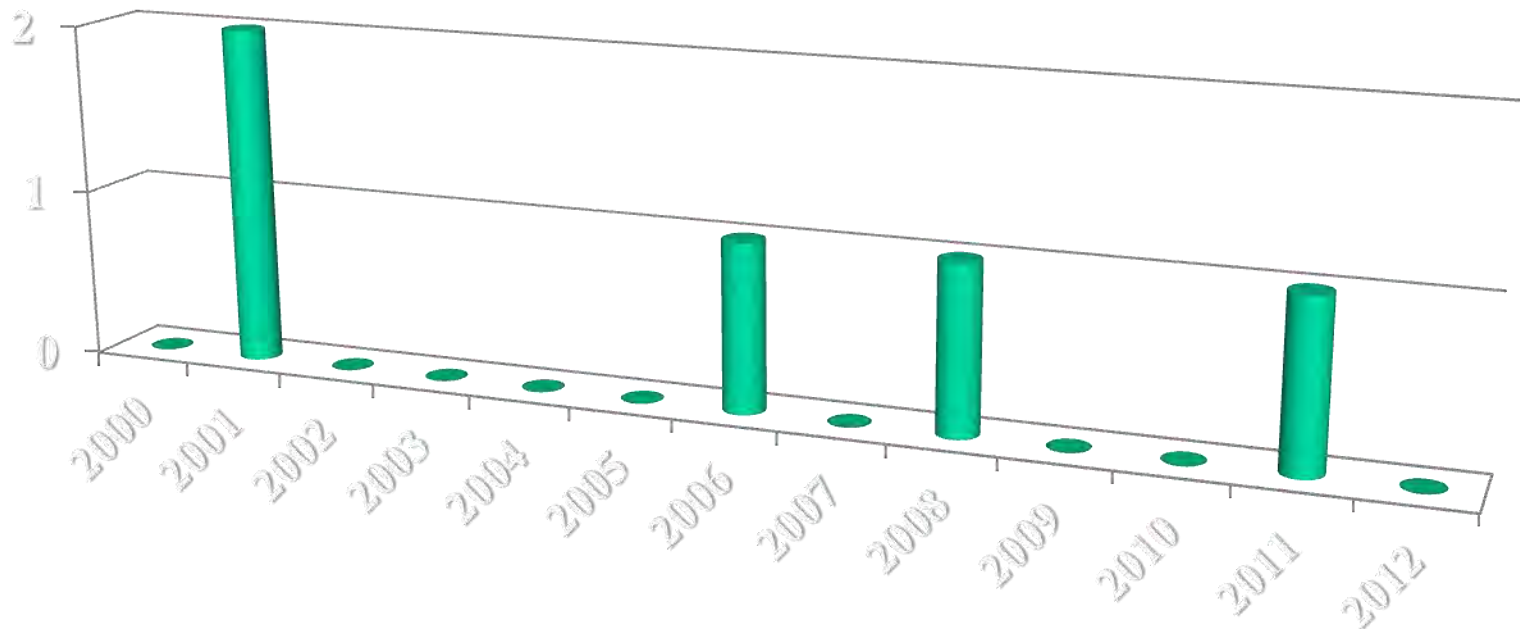
Overview

- G-tolerance
 - Definition
 - G-LOC mishaps in the USAF
 - Mechanisms of G-LOC
 - Characteristics of G-LOC
- Cardiovascular system and G
- Respiratory system and G
- Sources of G protection
- Factors diminishing G tolerance
- Review of VTR tapes
- “Bonus Material” – Neck injuries in the high G environment

What is G tolerance?

- The ability to withstand increasing force placed on the body by acceleration
 - Consciousness
 - Vision
 - Function
- Usually an expression of G_z , or G forces exerted vertically on the body by acceleration in that same orientation

The Numbers: USAF Class A G-LOC Mishaps



5 Class A GLOC Mishaps since 2000

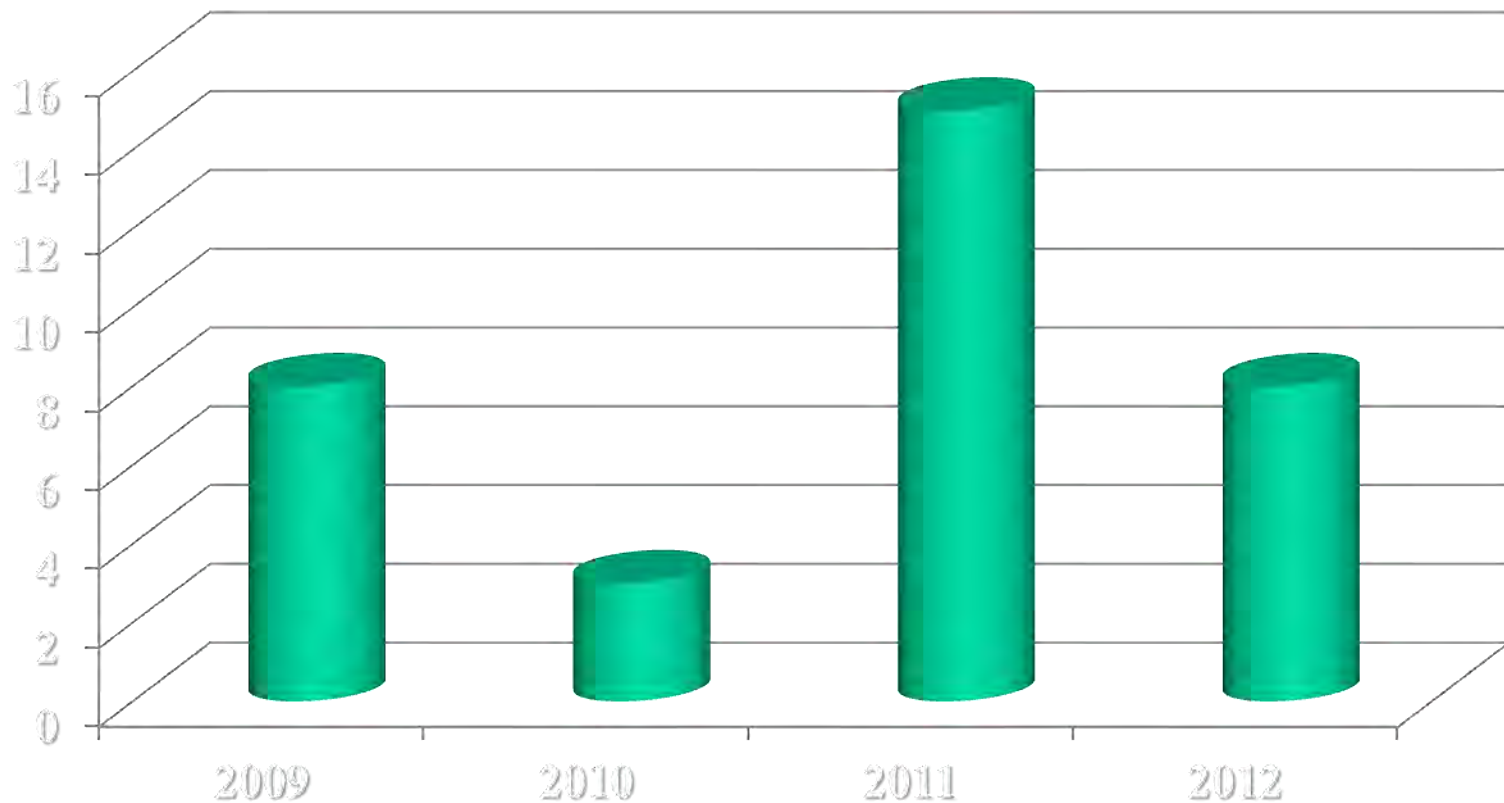
Class A: Loss of life/disability, A/C, or \$1M

Class A G-LOC by Aircraft



2000 – Sept 2012

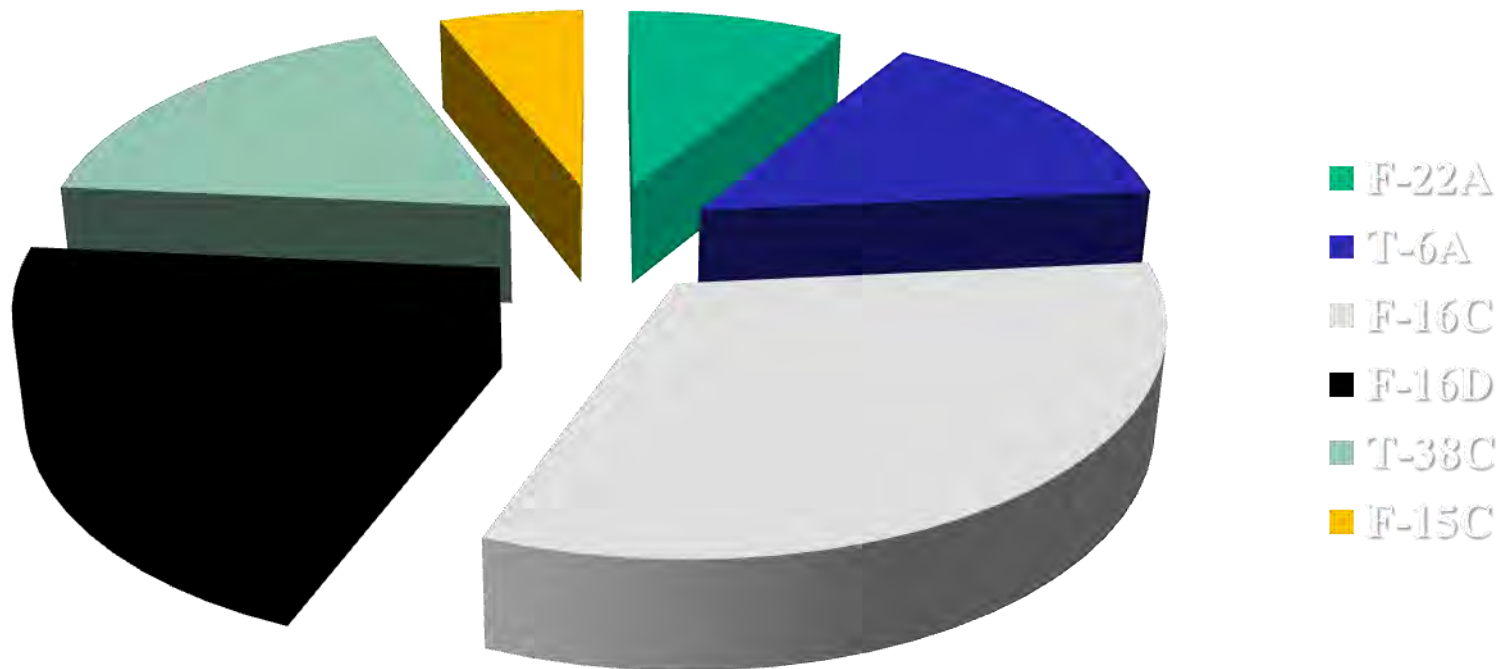
USAF Class E Physiologic G-LOC Events



Class E event not a reportable mishap, but
high potential for injury/illness/damage

USAF Class E G-LOC by Aircraft

2009-2012



Mechanisms of G-LOC

- Hydrostatic pressure drop at cranium level
 - Pressure Head = ht column X density fluid X G,
 - Avg 340 mm distance, blood is 1/13.6 density of Hg
 - $340 \times 1/13.6 \times 1 = \text{PH (BP drop) of } 25 \text{ mmHg/G}$
- If avg SBP is 120 mm Hg, avg cranium level BP is 95 mmHg at 1G ($120-25=95$)

Mechanisms of G-LOC

- At 5G, predict that the pressure head cannot perfuse the brain
 - $120 \text{ mmHg} - (5 \times 25 \text{ mmHg}) = -5 \text{ mmHg}$
- Blood pooling in lower body
 - ↓ Venous return
 - ↓ Cardiac output

Vision Loss

- Intraocular pressure 20 mmHg
 - Retinal artery pressure unable to penetrate the globe at a lower level than intracranial pressure
 - Insufficient for vision at a lower G level compared to brain function
 - Grayout then blackout *usually* precede G-LOC

Vision Loss Cont.

- Symptoms
 - Grayout first, still awake
 - Blackout
 - Loss of consciousness

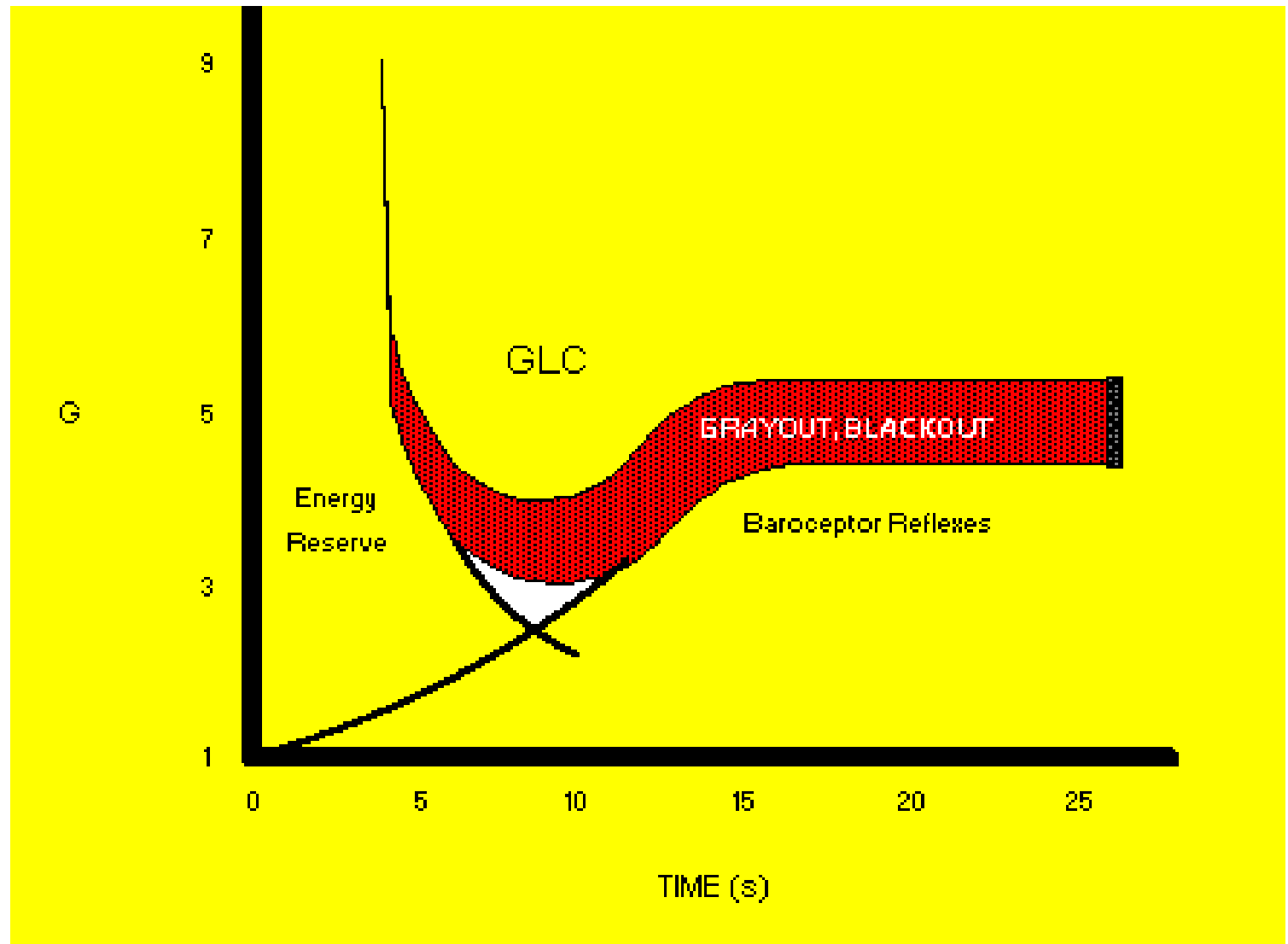
Characteristics of G-LOC

- MAY BE NO VISUAL WARNING
- **Average incapacitation times:**
 - 12 sec of absolute incapacitation
 - 4 sec of convulsive activity
 - Followed by 12 sec of confusion and disorientation
 - 24 sec total some degree of incapacitation
- Amnesia for the event is common
- No CNS damage

Internal Protective Mechanisms

- Metabolic reserve – about 5 sec
 - High energy phosphates in neural tissue
- Baroreflex
- Inadequate to maintain perfusion above a certain level – Resting tolerance

G-Time Tolerance Curve



Cardiovascular Symptoms

- Grayout
- Blackout
- LOC
- Convulsions
- Amnesia
- Confusion
- Cardiac Dysrhythmias
- Heart Block
- Stress Cardiomyopathy

Cardiac Dysrhythmias

Rank #		Dysrhythmia
1	1566	Sinus Arrhythmia
2	1073	PVCs
3	768	PACs
4	546	Sinus Bradycardia
5	372	Ectopic Atrial Rhythm
6	272	PJCs
7	171	PVC w/ Bigeminy/Trigeminy
8	104	AV Dissociation
9	104	PVC Pairs

Based on exposure of 554 individuals to 9831 +Gz centrifuge runs

Cardiac Output

- Despite increase in heart rate, cardiac output probably decreases under +Gz acceleration
- Heart rate response has not been shown to be predictive of G-tolerance

Respiratory Symptoms

- Altered ventilation/perfusion ratios
- Airway closure
- Atelectasis
- Compromised chest wall mechanics
- Pulmonary edema
- Disruption of anatomical integrity of lung

Respiratory Effects

- Increased respiratory rate
- Increased tidal volume
- Increased physiologic dead space

Means of Increasing G Protection

- Mechanical
- Physiologic
- Educational



Mechanical Means of Increasing G Tolerance

- Properly fit G-suit
 - Main benefit in abdomen
- Assisted positive pressure breathing - Combat EDGE
- Tilt-back seat (F-16)

G-Suit Protection

- Inflates at 1.5 psi/G above 2 G to maximum of 10 psi
- Snug fit responsible for 0.4 G of protection
- Inflation adds up to 1 G of protection
- Total 1 to 1.4 G of protection

ATAGS/FCAGS

- Advanced Tactical Anti-G Suit/Full Coverage Anti G Suit
- CSU-22/P Full Coverage Anti-G Suit to be implemented for all ANG F-15 and F-16 units
- Adds approximately 1-1.5 G of protection over CSU-13/P suit
- When combined with Combat EDGE, many do not need to strain at 9G (F-22 reports)
- F-16/F-15 pilots generally report increased tolerance

FCAGS

- Air bladders cover 90% of lower body vs 40% with legacy suit
 - Better pressure transmission = better tolerance
- Bladders cover legs circumferentially, but only front and sides of abdomen
 - Correct fit is essential to get the benefits
 - Abdominal fit more important than leg fit
- Time of year that fitting occurs matters
 - If fit in winter while wearing winter gear, FCAGS will be too loose when switch over to summer wear
 - Take home: If it feels loose, especially in the abdomen, have it refit

FCAGS

- FCAGS – additional 1-1.5 G of tolerance once fully inflated *above* the legacy suit
- Onset of protection somewhat slower
- Many but not all find improved high G (8-9 G) performance
- Results variable, **employ standard AGSM**
- Suit is hot, hydration essential for summer ops

Combat EDGE

- Positive pressure breathing under G
+12 mmHG/G over 4 G
- **Enhances G Endurance, not G Tolerance**
 - Less fatigue
 - Supposedly decreases requirement to strain by ~50%
- Less likely G-LOC, less fatigue

30 Degree Tilt-Back Seat

- F-16 only
- Unintentional fortuitous design
 - Not enough room for ACES II seat if left upright
- Pilots don't sit back in the seat!
- Adds 0.5-1.0 G of protection
- Due primarily to thigh elevation, not reduced heart-eye distance

Physiologic Means of Increasing G Protection

- Modified L-1 maneuver (definite)
 - Avg 4 G of protection
 - Navy uses “hook” maneuver (you are welcome to come up with a memory device for that)
- Frequent G exposure (definite)
- Weight training (probable)
- Moderate aerobic training (probable)

VTR Assessment

- Required by ACC, USAFE, PACAF, AETC
- Flight/CC & above or FS assess tapes for AGSM quality
- One review for each pilot at least once per half year
- Don't just look at G-awareness turns, look at mission; listen to your pilot when you fly

AGSM Maneuver

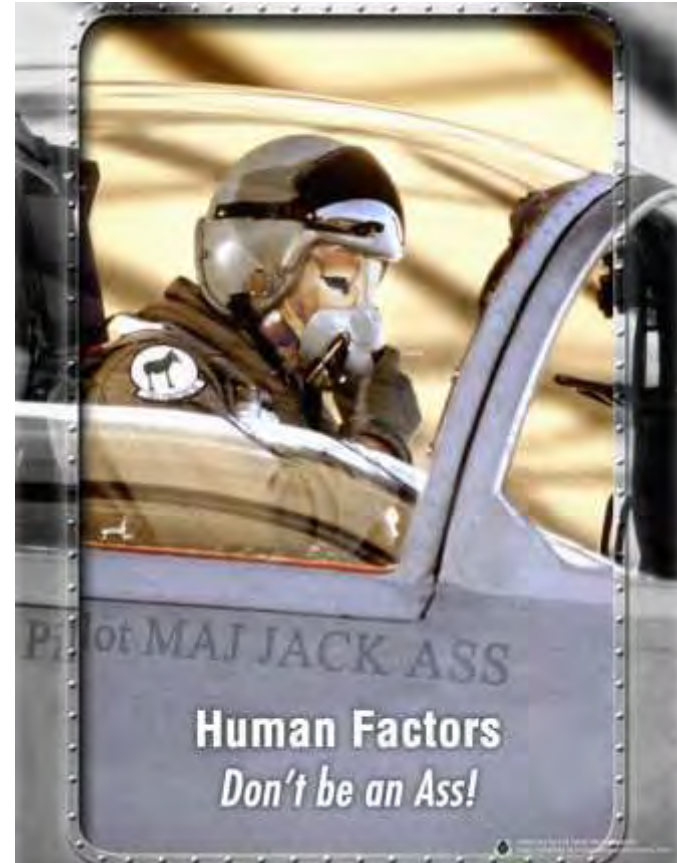
- Lower body muscle tensing – abs and glutes critical
 - First part of maneuver; prevent LE blood pooling
 - (Formerly taught upper body as well)
- Modified L-1
 - Second part; push the blood up to the brain
 - Closed glottis
 - 2.5-3.5 second strains
 - Quick, short breath between strains
 - 30-50% lung capacity

Educational Means of Increasing G Protection

- G Hazards Briefings
- Centrifuge Training
 - Standard for F-15C: +8.5G X 15 sec
 - Standard for F-15E: +7.5G X 15 sec
 - Standard for F-16: +9G X 15 sec
 - Brooks City Base TX (as of late 2013, projected to move to USAF SAM at WPAFB, OH)

Factors Diminishing G Tolerance

- Illness or layoff after illness
- Dehydration
- Fatigue
- Poor L-1 maneuver
- Excess EtOH
- Poor nutrition



Evaluation after G-LOC Episode

- Class E Mishap: Physiologic event
- Requires standard report
 - 72 hr & 14 day history
 - Toxicology studies
- Physical exam
 - Cardiovascular
- Lab/etc
 - EKG, CBC, glucose
- Assess VTR for AGSM (keep recording!)

Implications of G-LOC

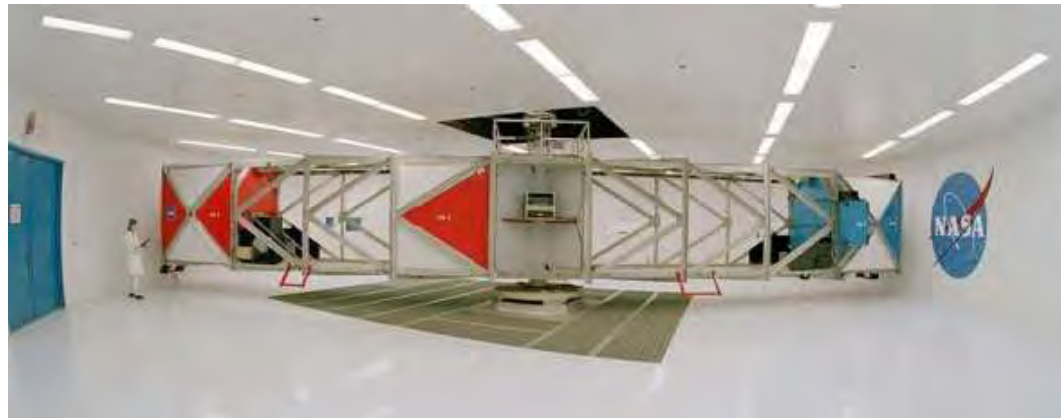
- Can result in inappropriate aircrew DQ if not handled properly
- Can result in loss of aircrew and aircraft
- Rarely may be an indication of cardiovascular problems
- Substandard G-tolerance an **administrative** issue

Aeromedical Disposition after G-LOC

- No grounding if:
 - Evaluation normal and faulty strain or disconnected G-suit responsible
- Instruct pilot on proper strain technique
- Centrifuge for FTU students
- Recheck AGSM on VTR from subsequent missions

Means of Increasing G Protection

- Mechanical
- Physiologic
- Educational
- Or, if you want to get across to fighter pilots...



Teaching a Fighter Pilot: How Can I Keep G-LOC from Happening to Me?

- Education
- Equipment
- Effort

Education

- Know how to protect yourself
 - Hydration
 - Nutrition
 - Exercise
 - Rest
 - Recent G exposure
 - G awareness for today – What is my tolerance and when will I be most vulnerable?

Equipment

- CSU 3-B/P G-Suit gives on average 1-1.5 G tolerance
- Combat EDGE provides increased G *endurance*, but not *tolerance*
- ATAGS/FCAGS provides additional 1.-1.5 G of tolerance over old suit
 - AGSM still essential
 - Suit is hot in summer, hydration in essential

Effort

- AGSM has two parts
- Muscular
 - Keeps the blood from pooling in your legs
- Respiratory
 - Helps the heart push the blood up the hill
- Timing matters

BONUS MATERIAL!

Neck Injuries and G Exposure

- Reported Injuries
 - Fractures of vertebral bodies or spinous processes
 - HNP
 - Ligamentous tears
- 30% incidence of mild neck injuries among F-16 pilots during training
 - F-16 community notorious for acceleration-related injury

Mitigating Risk of Neck Injury

- Conditioning – Make neck strengthening and stretching a priority for the workout
- Getting ready to fly – Stretch the neck before stepping and/or in the jet before takeoff
- Set before pull – Instruct pilots to turn and extend neck as necessary before loading the jet whenever possible

Summary and Take Home

- G-tolerance
- Respiratory system and G
- Sources of G protection
- Factors diminishing G tolerance
- Review of VTR tapes
- When teaching aircrew to protect themselves, keep it simple
 - Education
 - Equipment
 - Effort
- Next slide for quiz instructions

- [Go to quiz](#)
- Enter your answers on the [answer sheet](#)
- Print only one answer sheet for entire course
- Press ESC to go back to main menu