



Ocular Impacts of Prolonged Space Flight

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Space and Occupational Medicine Branch
NASA Johnson Space Center

Aerospace Physiology Society Luncheon
Aerospace Medical Association – 89th Annual Scientific Meeting – 09 May 2018



Background: *My Assignment*



- Detailed via **DoD Executive Secretary, Office of Secretary of Defense (OSD)**
 - 3-year tour (PRD: Oct19)
 - Occupying **9999 billet** (“General Group”)
 - Stationed at **NASA Johnson Space Center** (Houston, TX), w/in **Space Medicine Operations Division**
- Interact routinely with...
 - Clinicians (i.e., flight surgeons, optometrists, etc.)
 - Scientists
 - Trainers
 - Astronauts/cosmonauts – Terrestrial & on-orbit
 - External Subject Matter Experts (SMEs)
- Primary duty: Support efforts associated w/
Spaceflight Associated Neuro-ocular Syndrome (SANS)





Background: *Johnson Space Center*





Background: *Johnson Space Center*





Background: *ISS*



■ International Space Station (ISS)

- In use since 2000
 - 54 expeditions completed
- U.S. $n^* = 61$ (as of Dec17)
- Duration: ~0.5 to 1y
- International partners
 - United States
 - Russia
 - European Union
 - Canada
 - Japan
- Crew: Typically 5-6
- “Low Earth orbit”



* Person flights; may include multiple-time flyers w/in program



Background: *The Future...*



- The space environment: *Not human friendly*
- NASA plans to send astronauts outside of Earth's magnetic & gravitational fields in 2020s
 - Moon return?
 - **Mars missions in 2030s. Duration: 2.25 to ~3 yrs**
 - Unprecedented challenges to health & performance
 - Top NASA human research priorities for expeditionary missions
 - Radiation risks
 - **Spaceflight Associated Neuro-ocular Syndrome (SANS)**
 - Behavioral health
 - Food & pharmaceutical stability
 - In-flight medical conditions





Recent SANS Headlines



Speaking of Science
Too much space travel is hazardous for your eyeballs

Spaceflight Bad for Astronauts' Vision, Study Suggests

By SPACE.com Staff | March 13, 2012 12:00am ET

Possible Mars Mission 'Showstopper': Vision Risks for Astronauts

By Mike Wall, Senior Writer | April 8, 2014 07:00am ET



Astronauts' eyes are at risk after too much time in space

Health & Science
The mysterious syndrome impairing astronauts' sight



Astronauts Returning to Earth With Vision Problems

Video Channels

POST ORIGINALS July 8, 2014

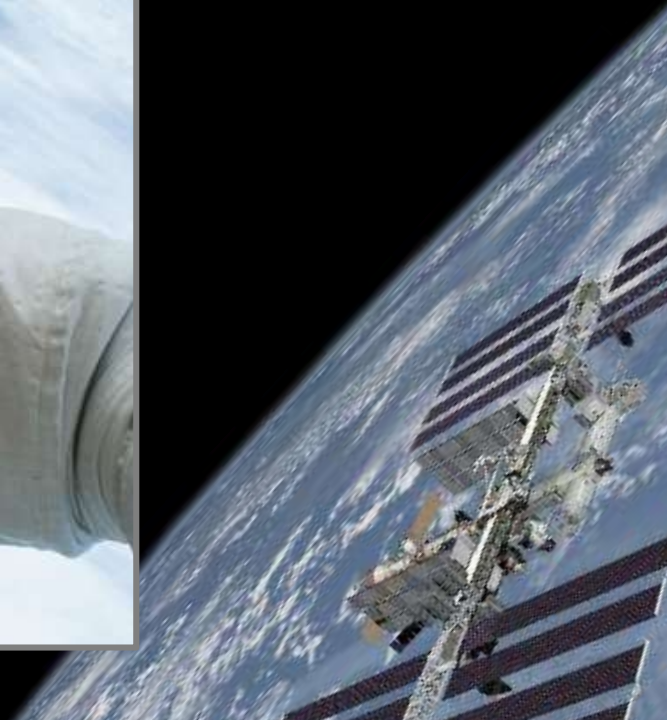
Space travel is causing visual impairment for some astronauts. Will this prevent travel to Mars?

The Washington Post

ght is bad for
it may cause vision



What's So Special About the Eye?

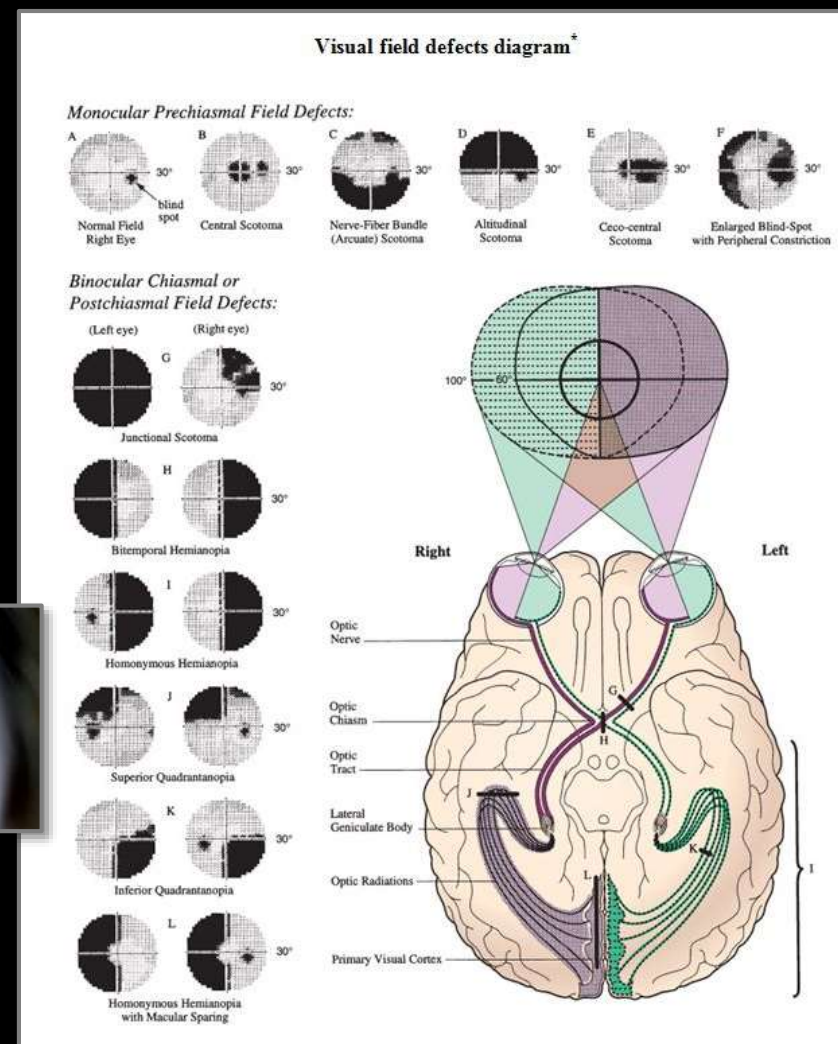




What's So Special About the Eye?



- Only about 1" in diameter, but...
 - Provides ~80% of our sensory input
 - Medical Emergency: "Life, limb, or eyesight"
 - Presents tremendous amount of health information
 - Neurological state (4-of-12 cranial nerves): via eye position, lid position, pupil size & reaction, visual performance
 - Tumor, aneurysm, stroke, etc.

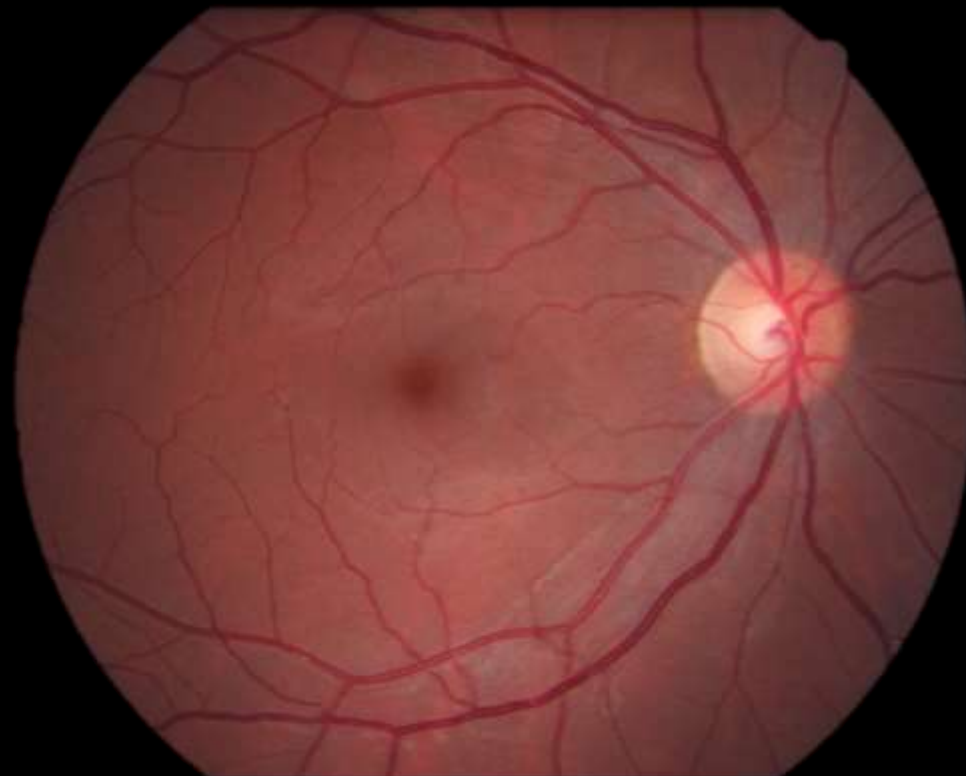




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 - Presence/severity of systemic disease
 - High blood pressure; diabetes; impending stroke; high intracranial pressure; hyperthyroidism; etc.



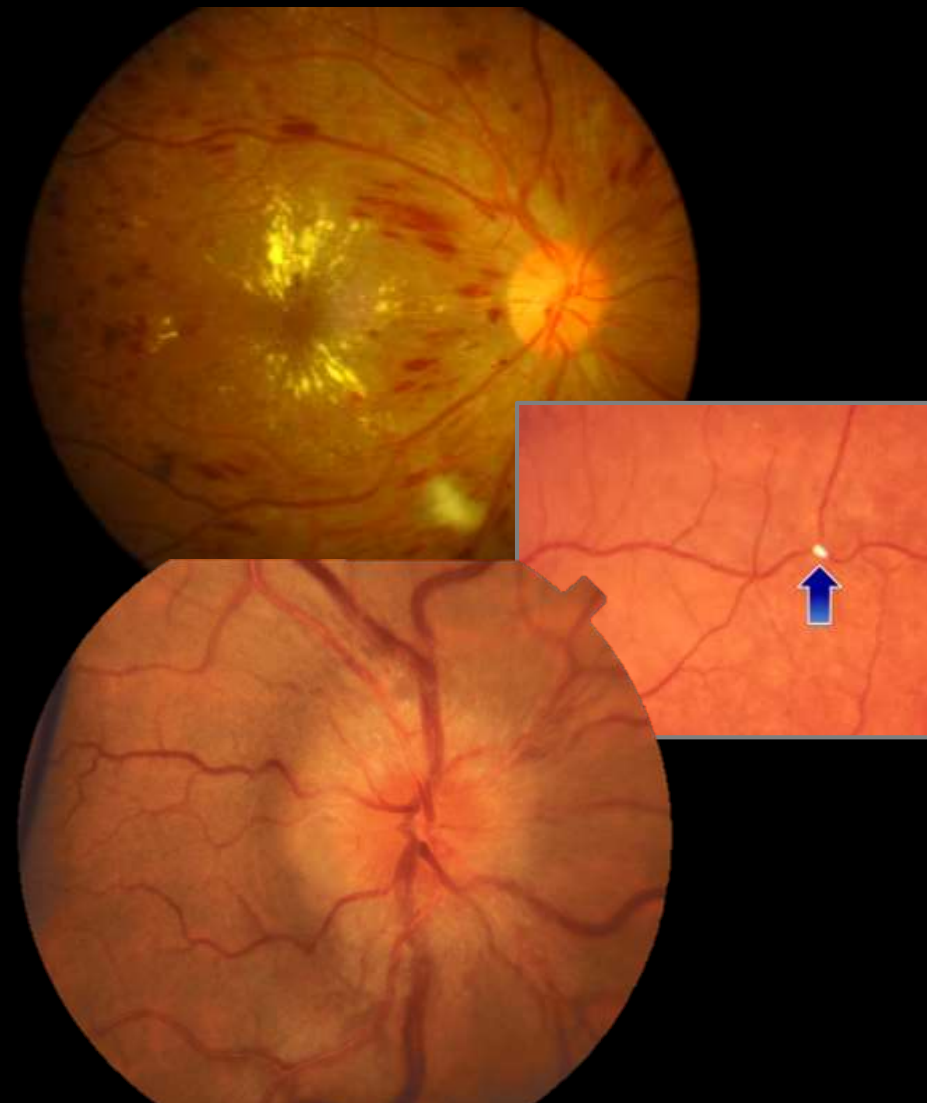
Normal view of eye's posterior pole:
Retina; optic nerve head (optic disc);
retinal blood vessels; macula



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 - "Window to the soul": ∴ Astronaut eyes have always been eval'd pre/post-flight by NASA





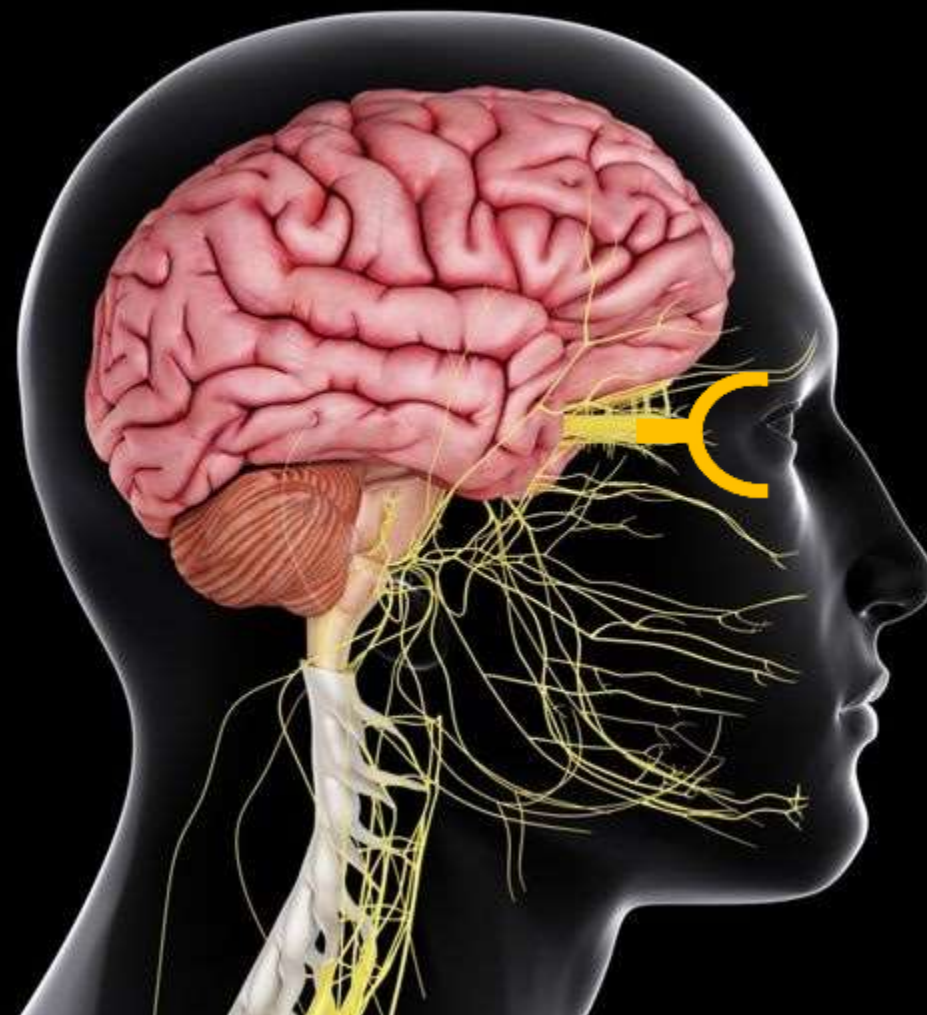
What's So Special About the Eye?



- Optic nerve, optic nerve head, and retina...

- *Central nervous system*

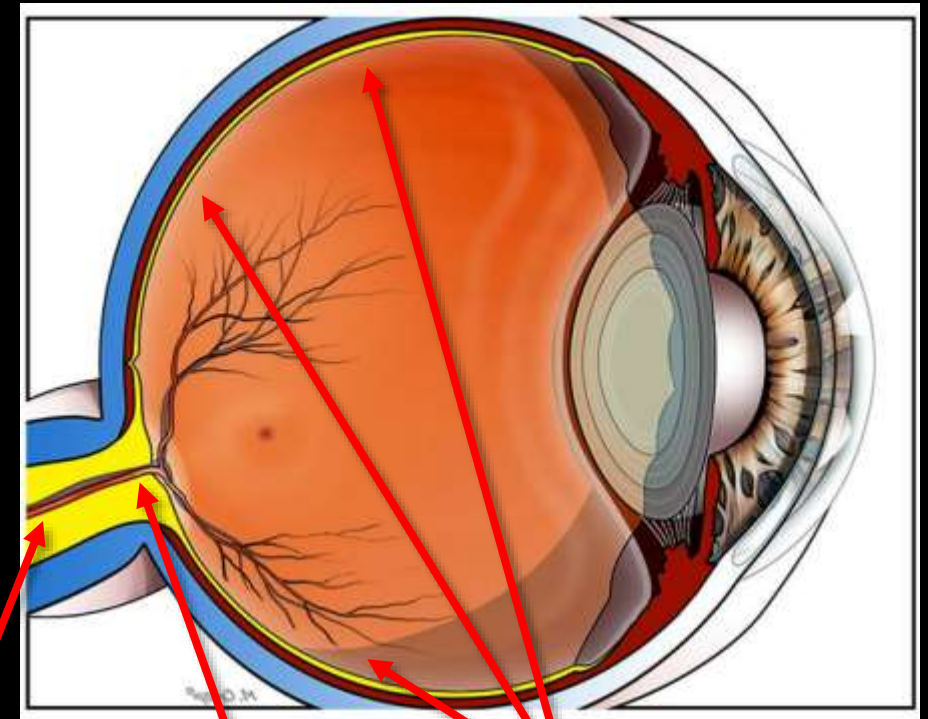
- Behind blood-brain barrier
- Susceptible to permanent loss



What's So Special About the Eye?

■ Optic nerve, optic nerve head, and retina...

- *Central nervous system*
 - Behind blood-brain barrier
 - Susceptible to permanent loss
- Optic nerve
 - Connects eye to brain
 - Bathed in cerebrospinal fluid (CSF)
- Optic nerve head (ONH) / “Optic disc”
 - Where optic nerve meets eye
 - Has *intracranial pressure* (ICP) on backside, *intraocular pressure* on frontside



Optic Nerve

Optic Disc

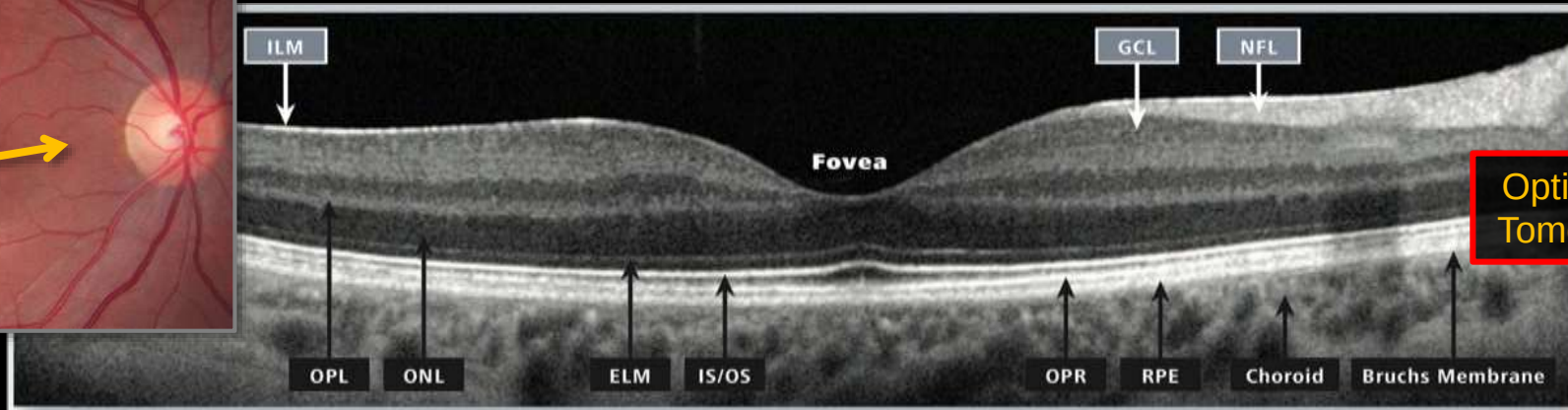
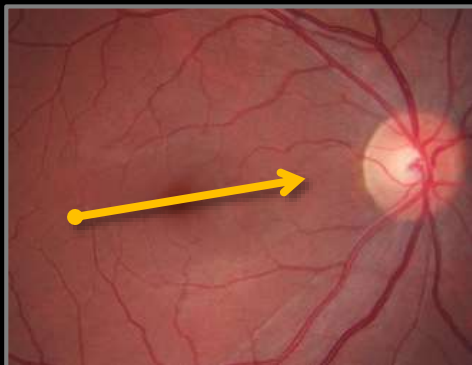
Retina

What's So Special About the Eye?

■ Optic nerve, optic nerve head, and retina...

• Retina

- Converts light energy into neural signals
 - Sends signals through nerve fibers (via disc & optic nerve) → brain → “vision”
- Extremely high metabolism: *High demands, low reserves*
 - Photoreceptor mitochondria operate at ~70-80% capacity
 - *Requires reliable, sustained blood supply* (O₂, glucose, etc.)

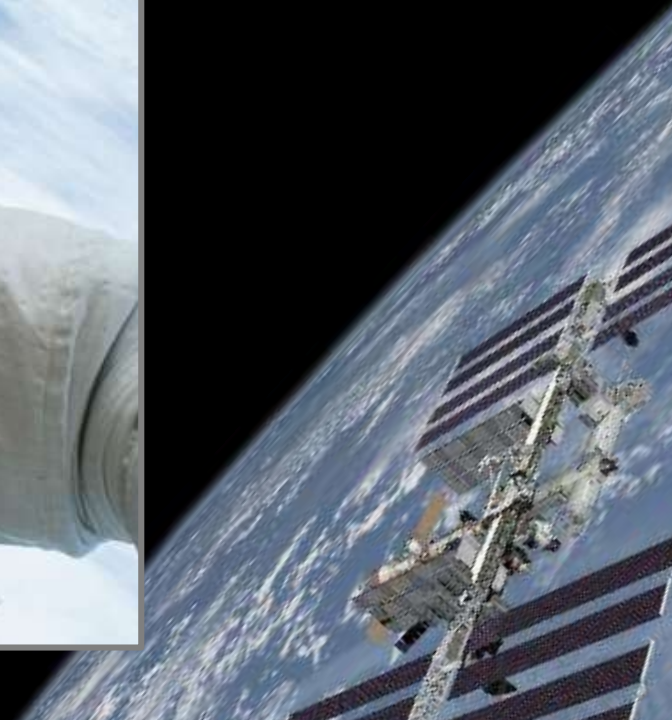


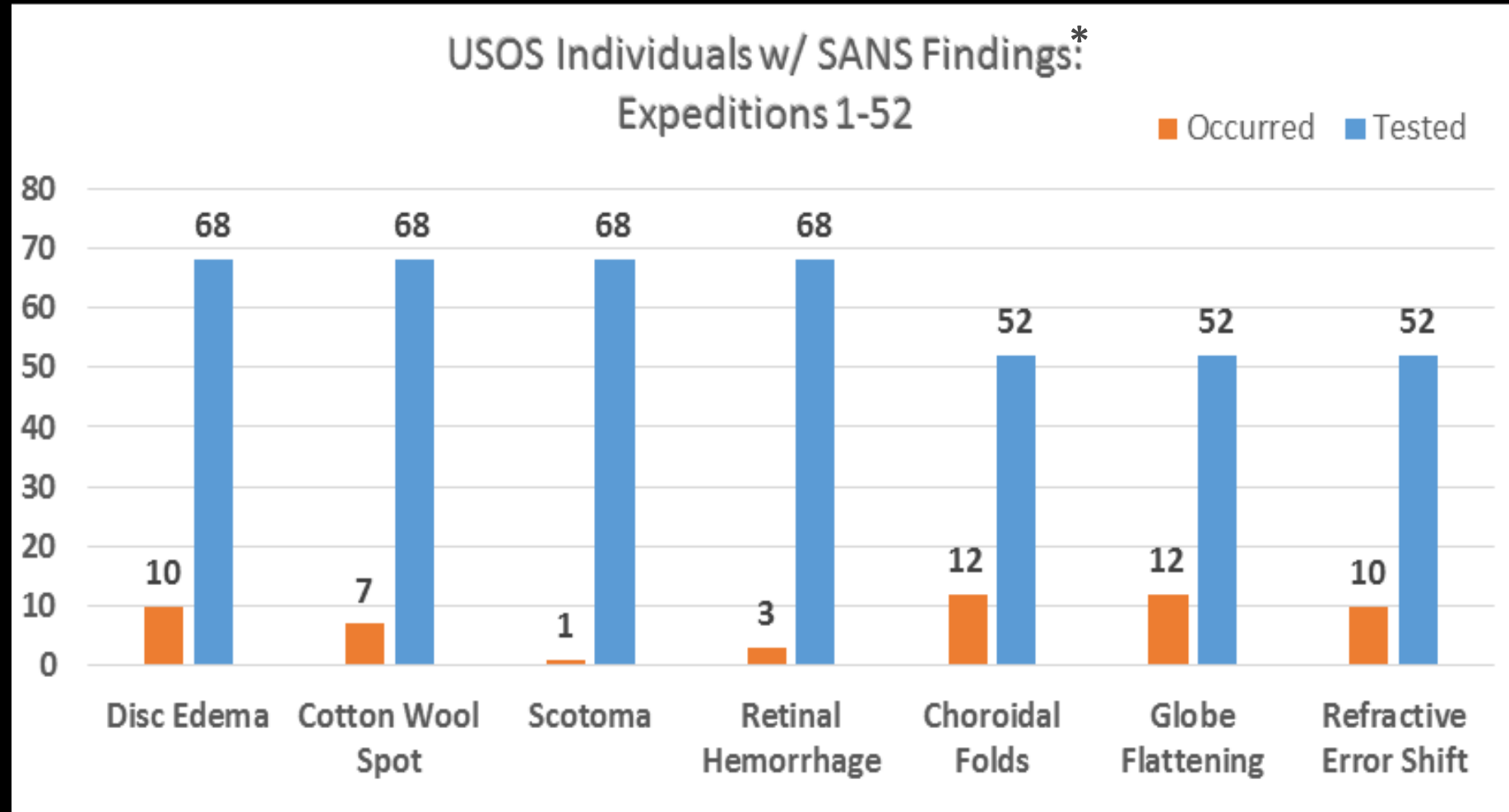
Optical Coherence Tomography (OCT)





SANS: Clinical Findings

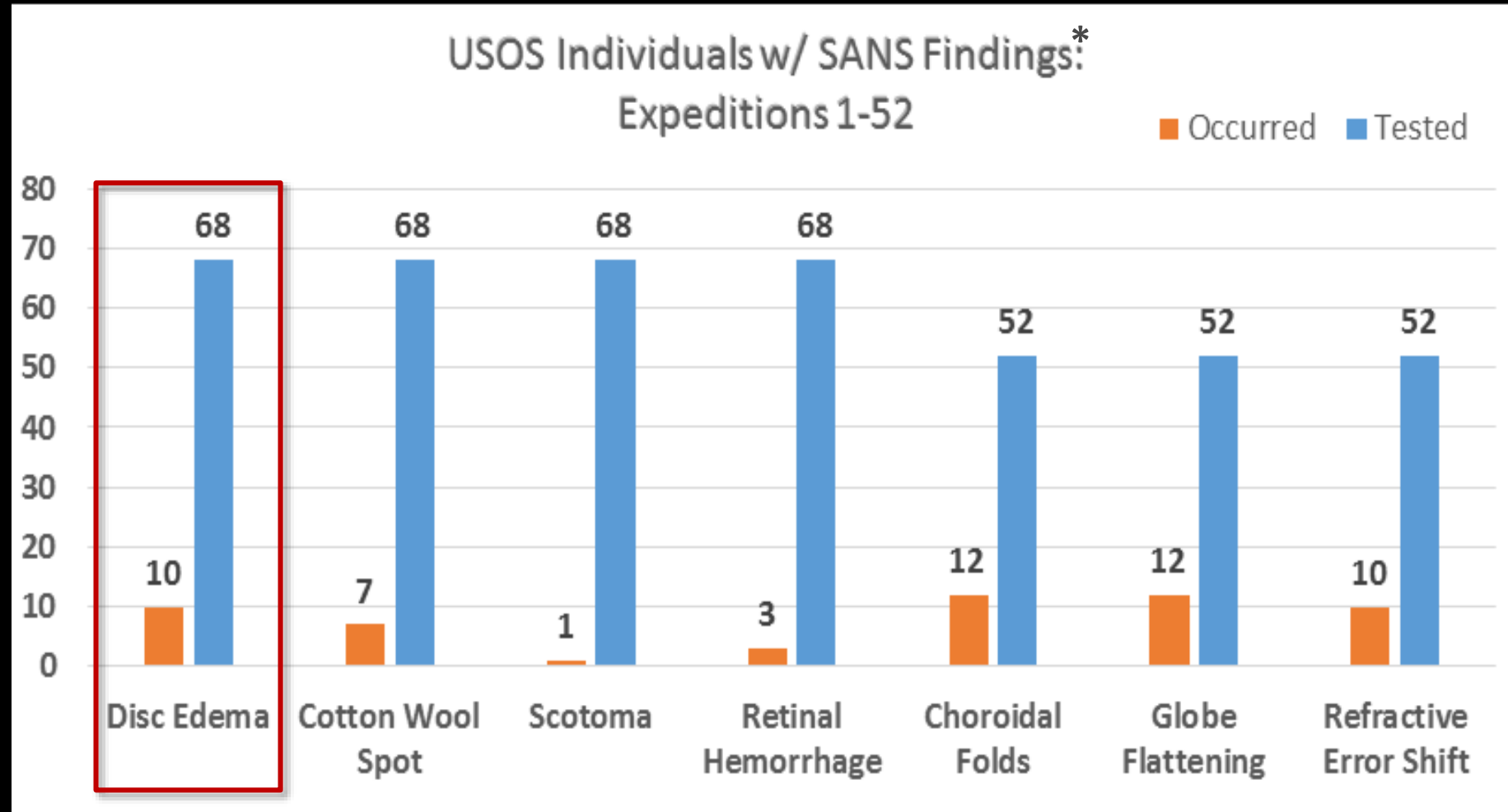




* Additional SANS signs not included: Optic nerve (ON) sheath distension, ON kinking/tortuosity, Retinal nerve fiber layer thickening, Retinal folds, Choroidal thickening. *Data analysis ongoing*



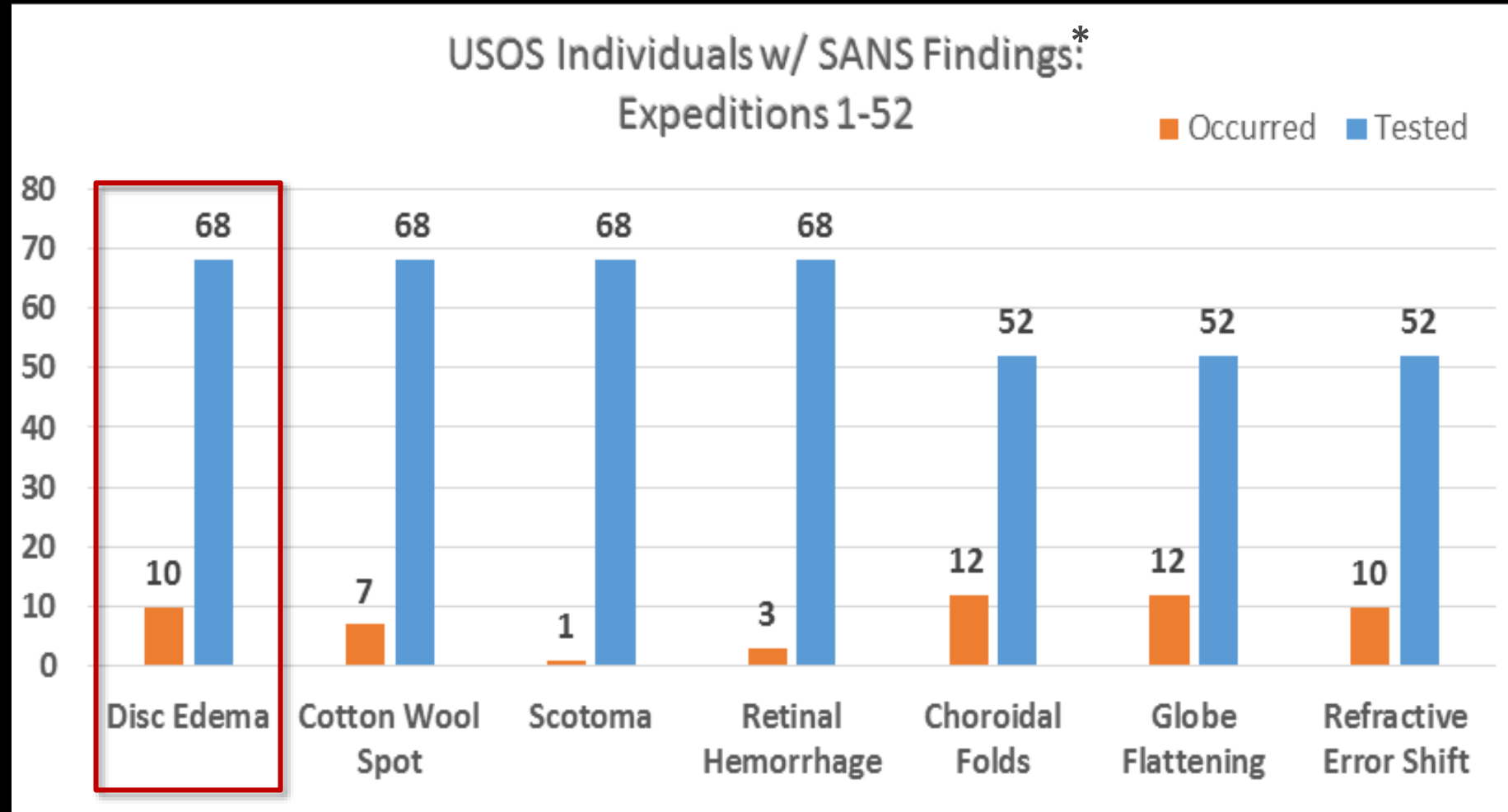
Pre-flight - OD



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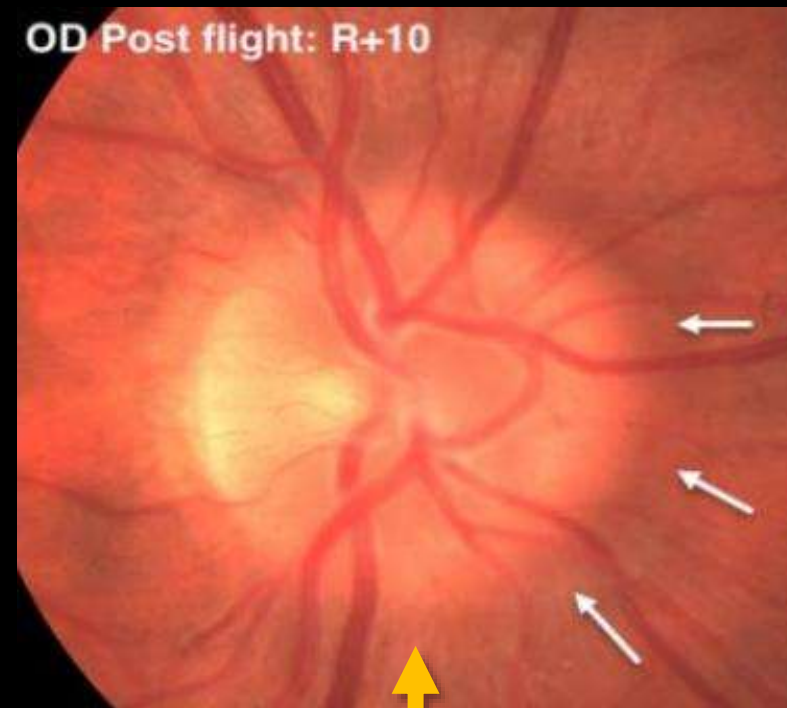
Post-flight - OD



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Clinical Findings: *Optic Disc Edema*

- *Edema: “Accumulation of excess fluid; swelling.”*
Indicates an underlying abnormal condition (pathology)
- *Terrestrially -- Disc edema typically associated w/:*
 - Unilateral: Optic neuritis/neuropathy, retinal artery occlusion, extreme hypertension
 - Bilateral: *Increase in ICP...*
 - e.g., Idiopathic intracranial hypertension (IIH)
 - Typically causes symptoms (e.g., for IIH: severe headaches, transient vision loss, double vision, enlarged blind spot, color vision impairment)
 - Edematous CNS neurons can atrophy, lost permanently, depending on severity & duration
 - Good News: So far, no obvious loss of ocular nerve tissue detected in astronauts



Fundoscopic image of optic disc OD, R+10 days. Arrows indicate “C” shaped halo of edema



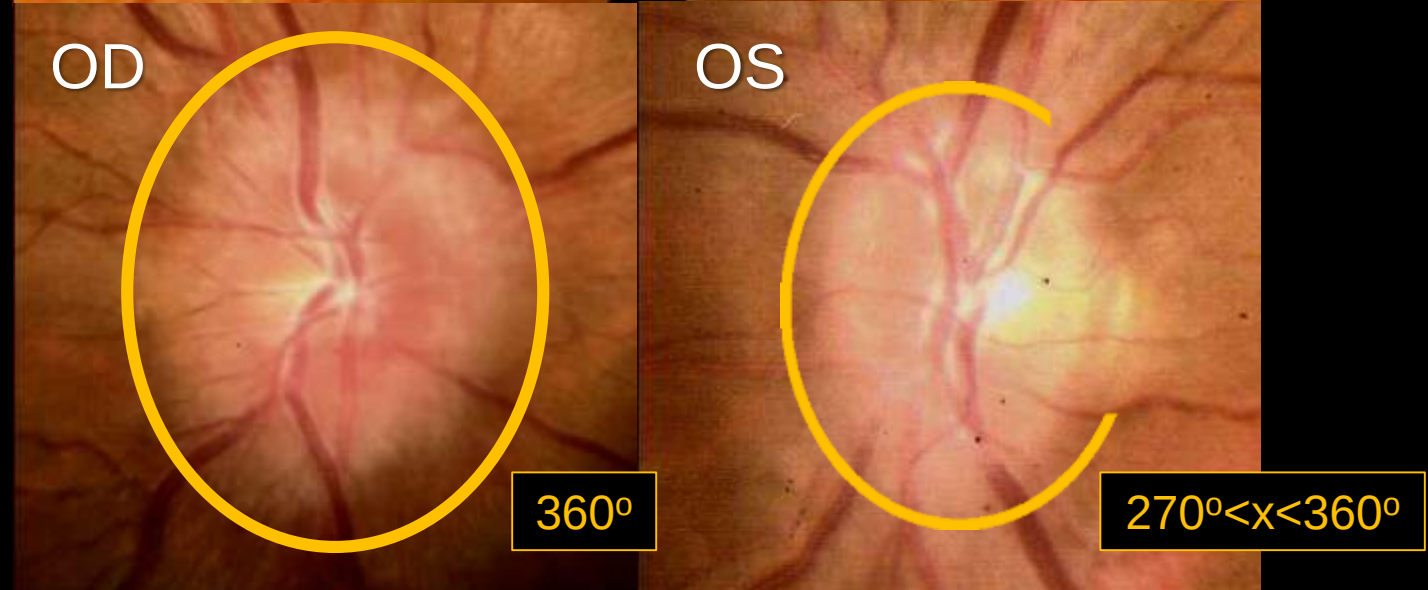
Clinical Findings: *Optic Disc Edema*



Pre-flight fundoscopic images of the optic discs



Post-flight images of optic discs, showing:
Grade 3 edema OD
Grade 1 edema OS



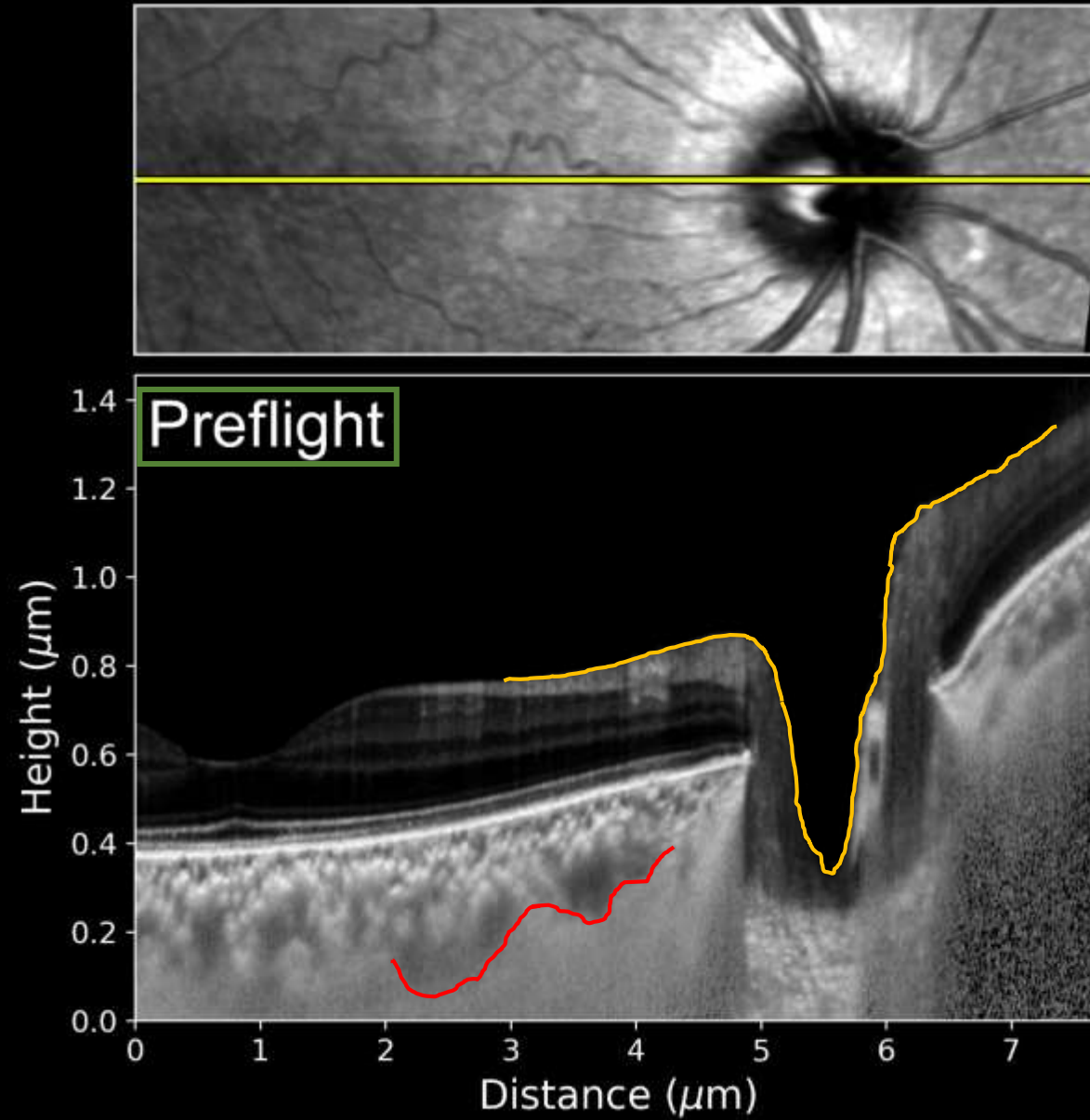


Clinical Findings: *Optic Disc Edema*

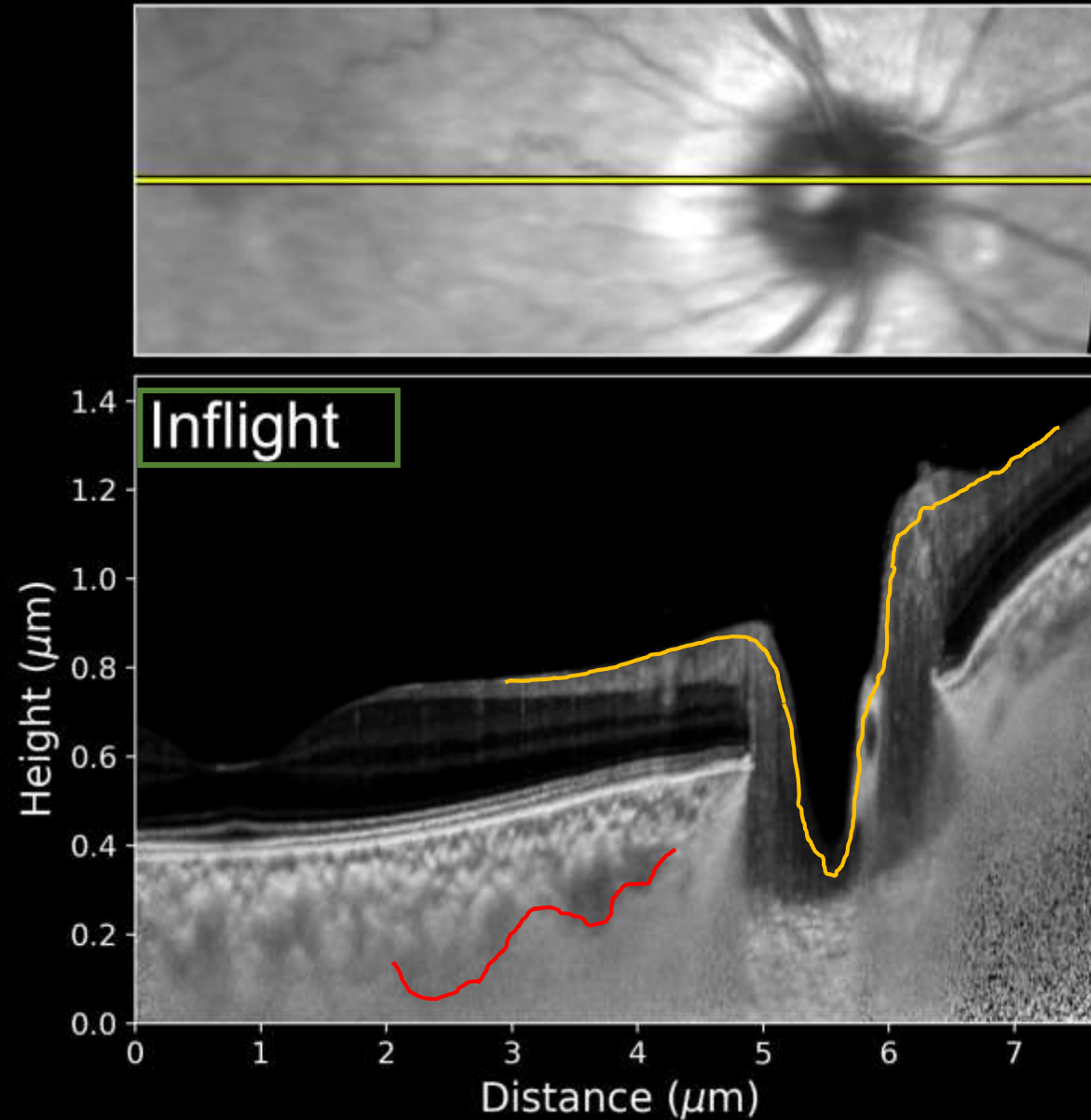
Recent Findings

- “Optic disc changes” w/ long-duration spaceflight
 - David Brown, MD – Retinal specialist; SANS Research & Clinical Advisory Panel
 - Analyzed 14 crewmembers having complete pre-flight & on-orbit OCT data, ALL showed signs of:
 - Choroidal thickening
 - Venous engorgement
 - Optic disc edema
 - And...optic discs tend to expand forward and backward (opposite to IIH)
 - Nimesh Patel, OD, PhD – OCT scientist/SME; analyzes all crewmember OCT data
 - Also described these edema & disc expansion findings

(Patel N, Pass A, Mason S, Gibson CR, Otto C. Optical coherence tomography analysis of the optic nerve head and surrounding structures in long-duration International Space Station astronauts. JAMA Ophthalmol 2018 Feb 1;136(2):193-200)

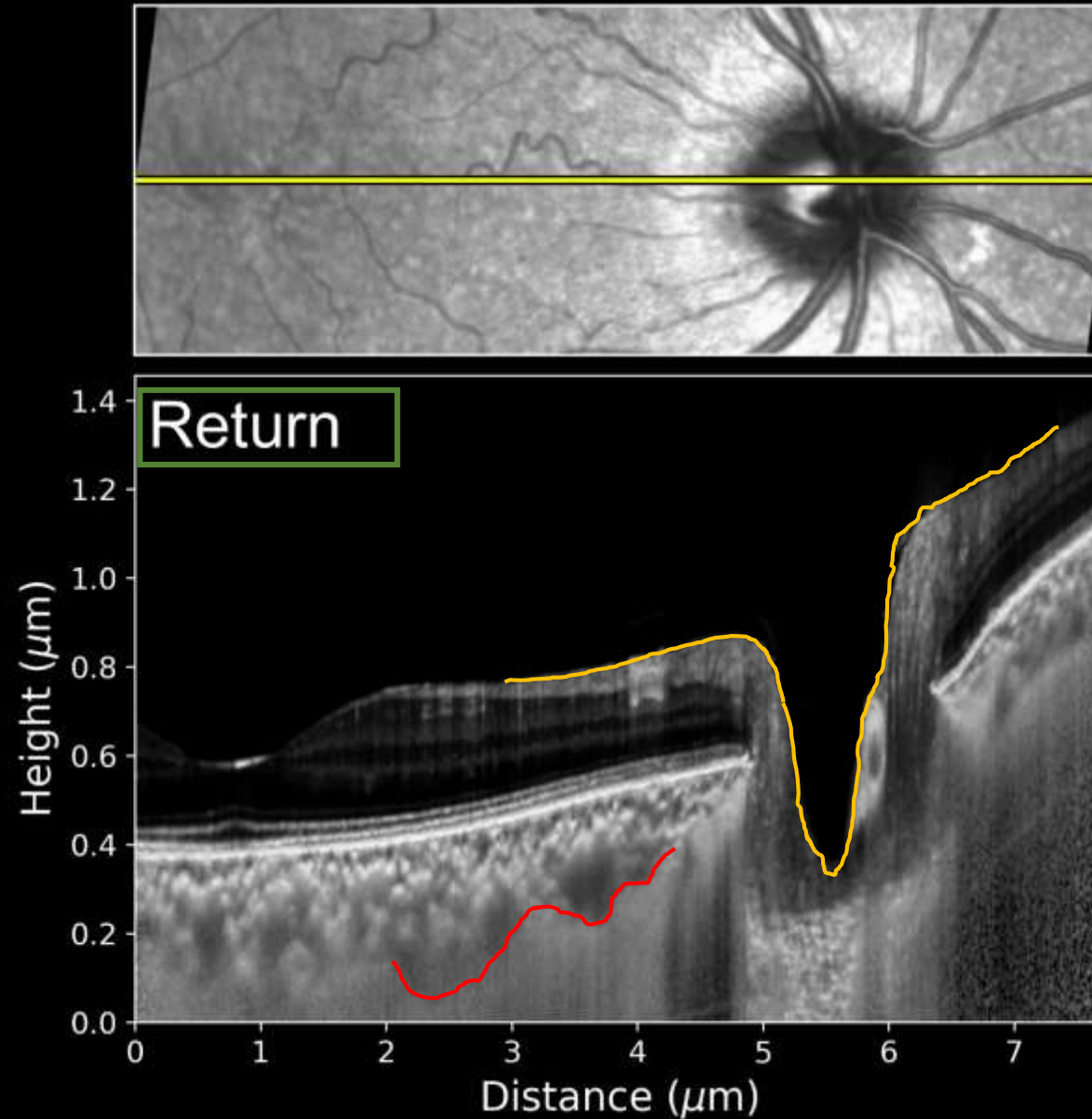


Source:
Mayra Nelman &
Simon Clemett



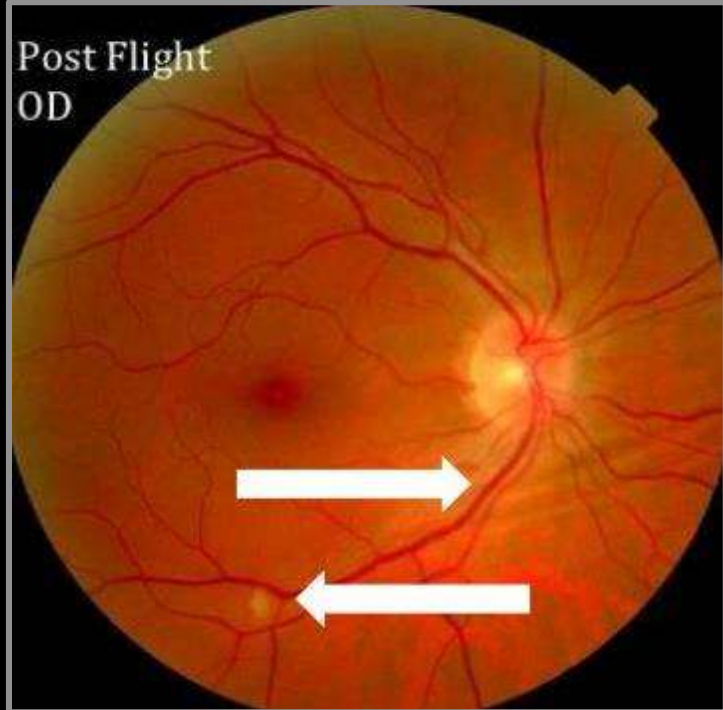
Non-Case w/
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edema”

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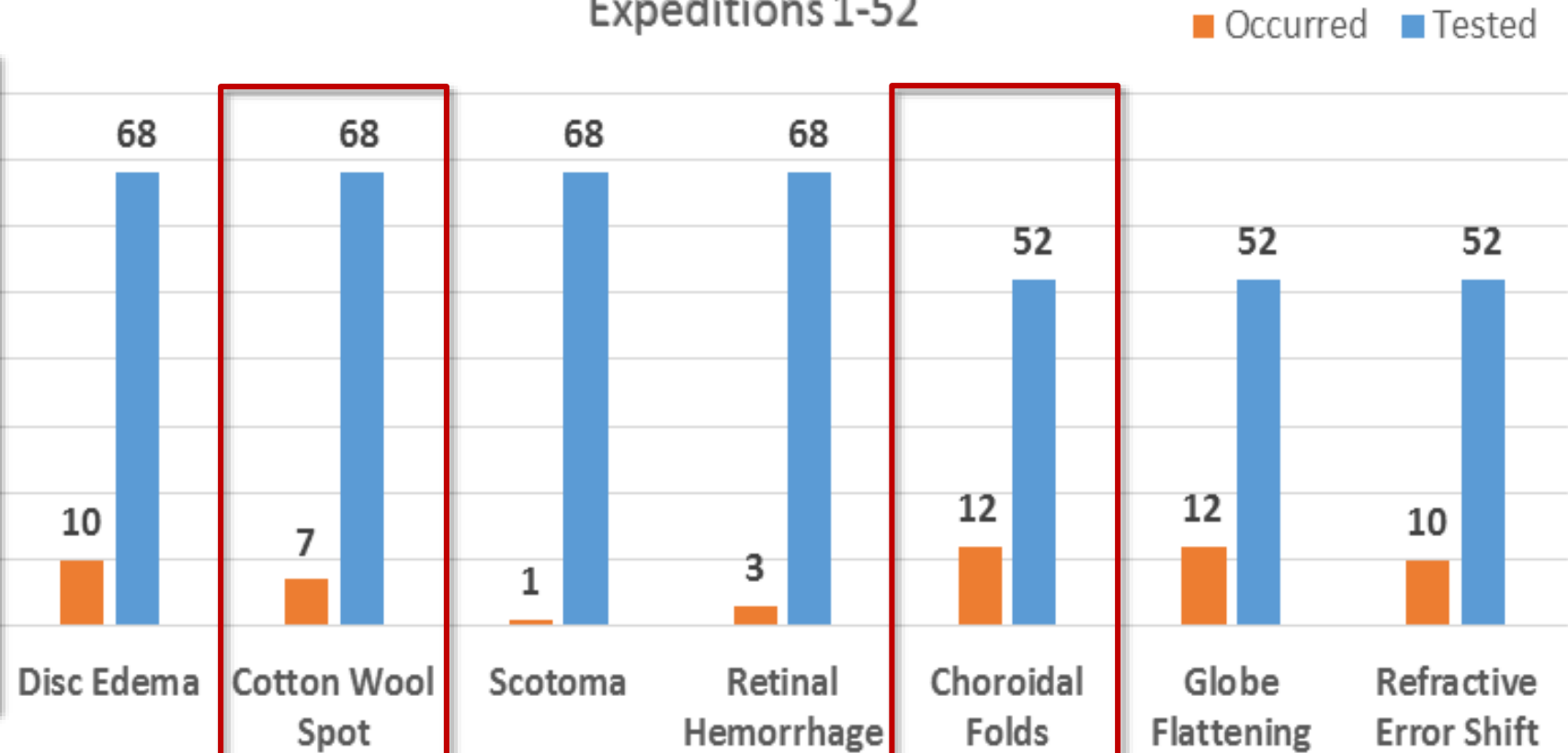


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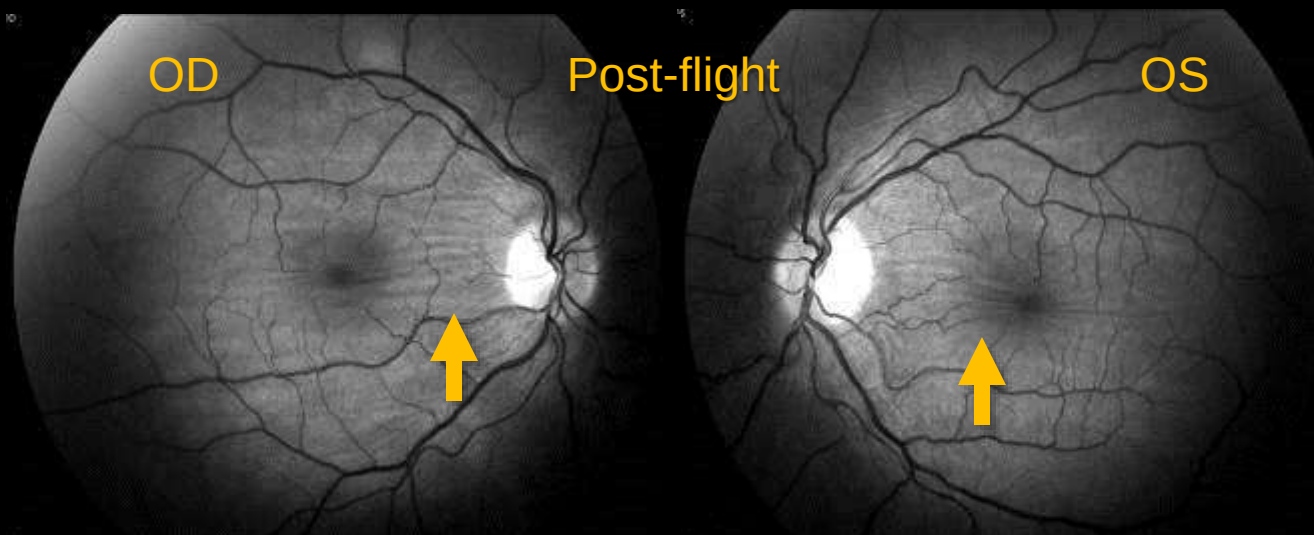


USOS Individuals w/ SANS Findings* Expeditions 1-52



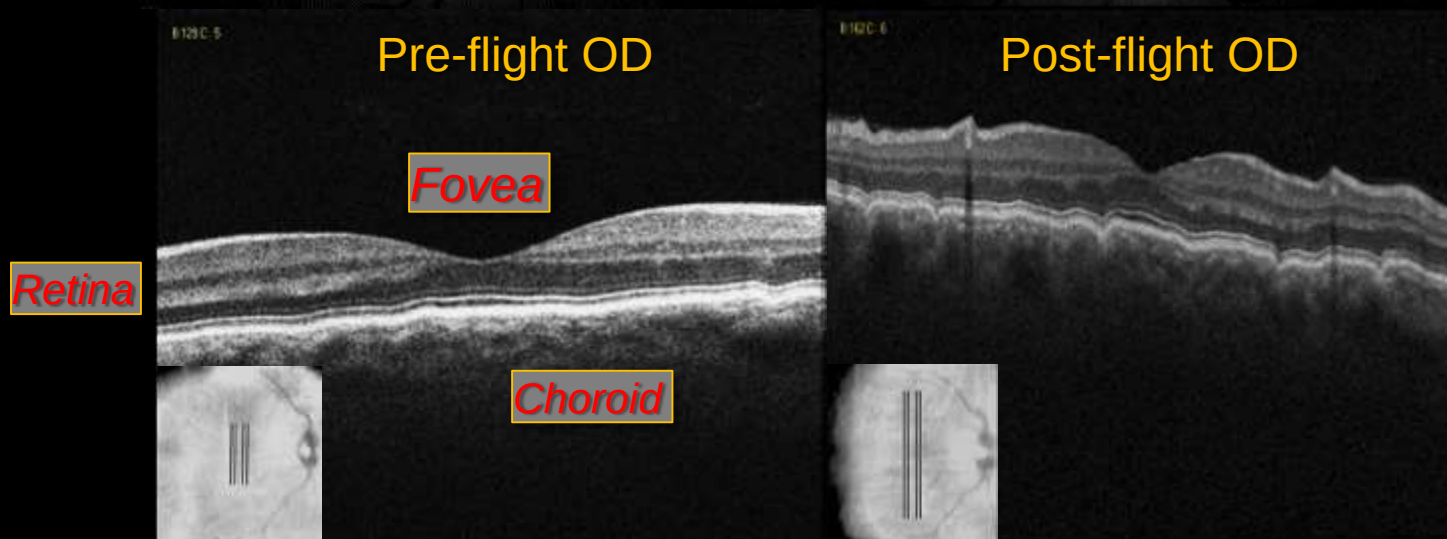
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Clinical Findings: *Choroidal Folds*

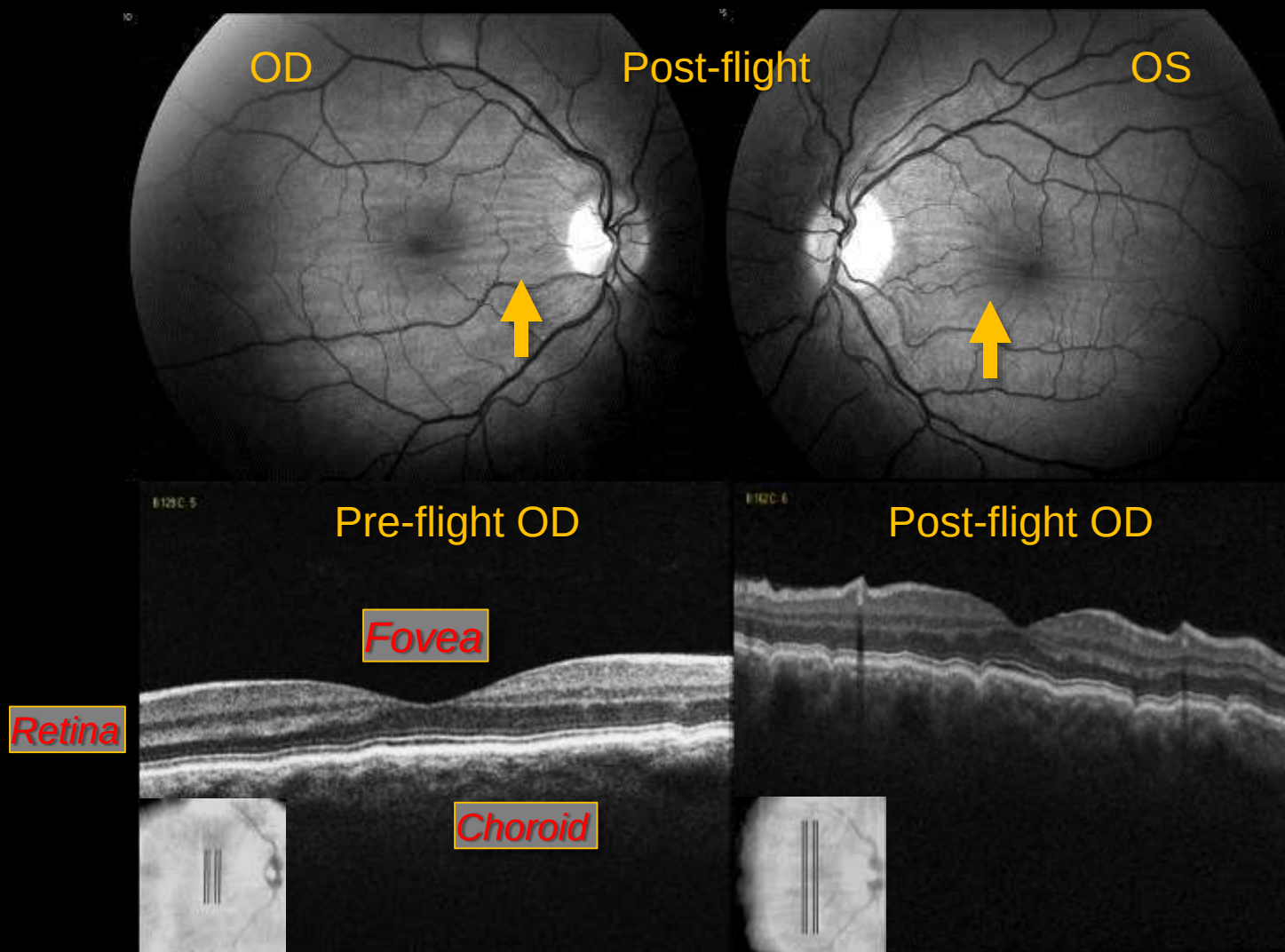


■ SANS cases:

- Choroidal thickening due to vessel engorgement → induces choroidal (and sometimes retinal) folds



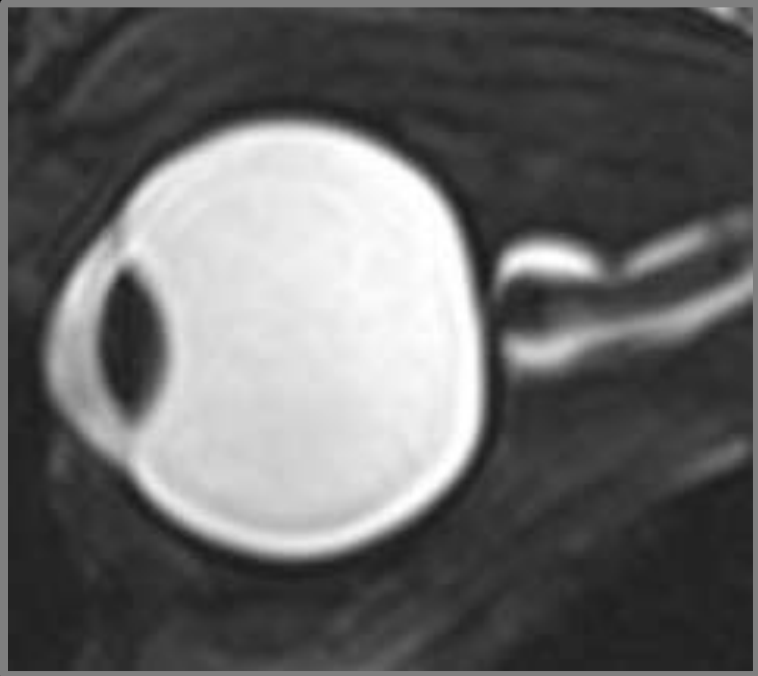
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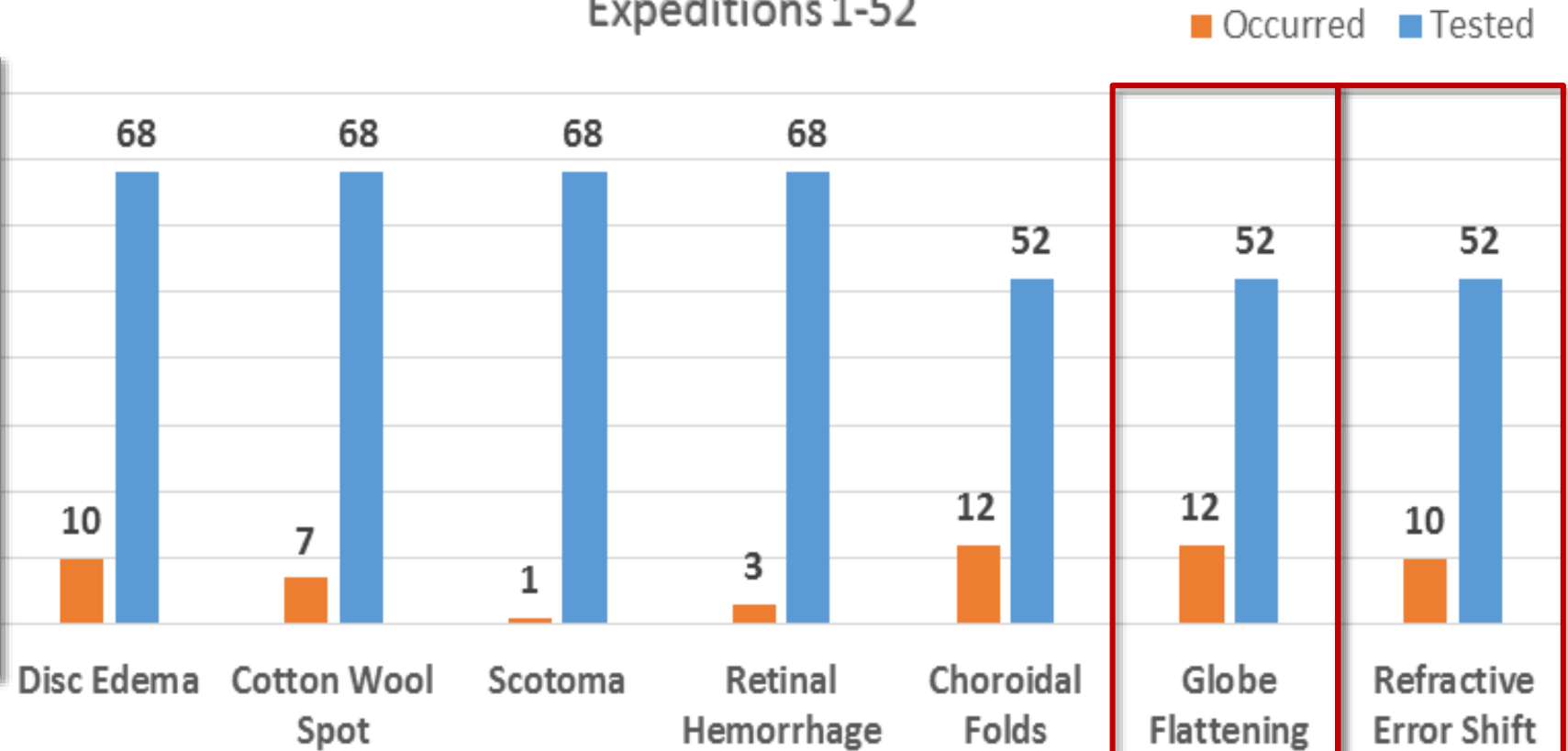
■ SANS cases:

- Choroidal thickening due to vessel engorgement → induces choroidal (and sometimes retinal) folds
- Usually run horizontally
- Can resolve post-flight or persist (for 12+ yrs)
- So far, no significant impact on best-corrected visual acuity (BCVA)...but is a significant risk

- *Terrestrially: Assoc. w/ choroidal or orbital tumors, scleritis, IIH*



USOS Individuals w/ SANS Findings* Expeditions 1-52



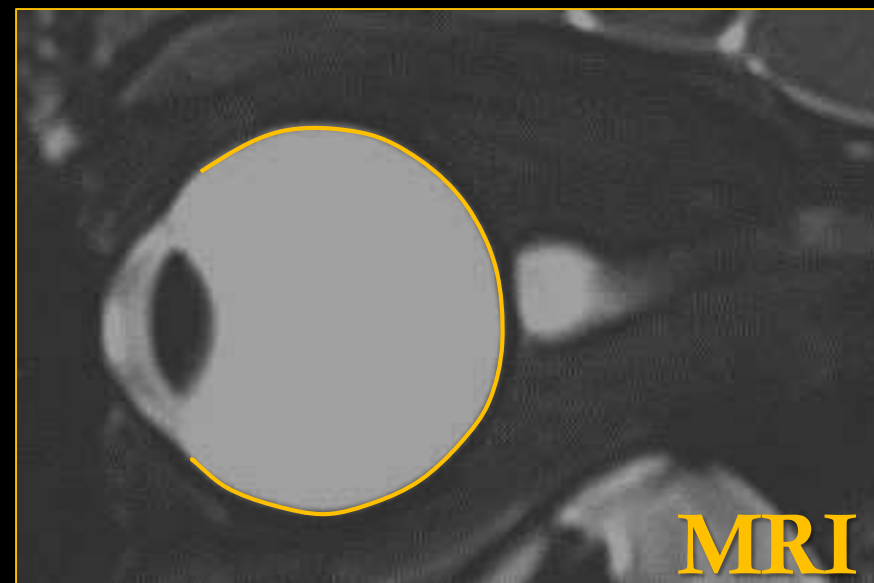
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Clinical Findings: *Globe Flattening*



- Can resolve post-flight or can persist (for 7+ yrs)
- Case Example:
 - Male, mid 40s at time of flight
 - No significant PMH/PSH/PFH
 - No meds
 - Normal BP (118/64)
 - Normal lipids
 - ECG Stress test normal w/ VO_2 max of 51ml/kg



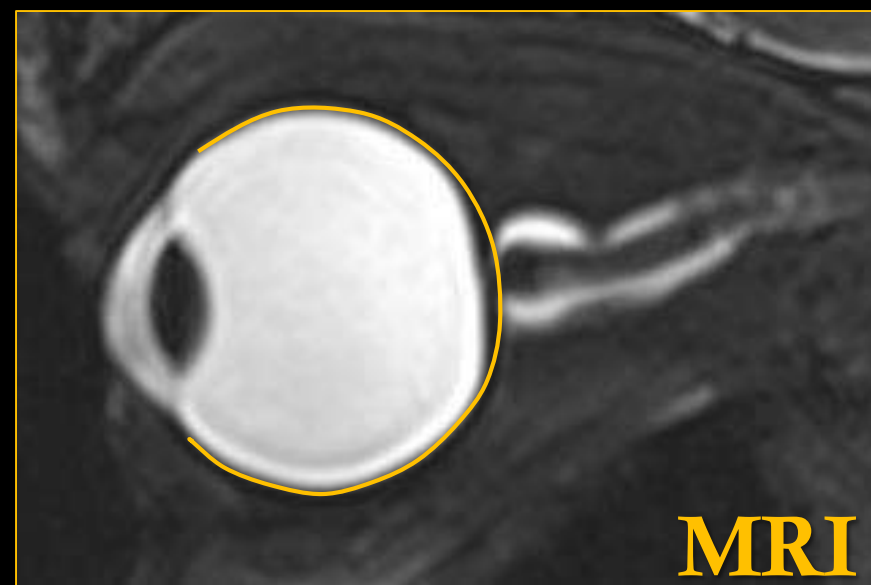
Pre-flight



Clinical Findings: *Globe Flattening*



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6 days post-flight



Clinical Findings: *Globe Flattening*

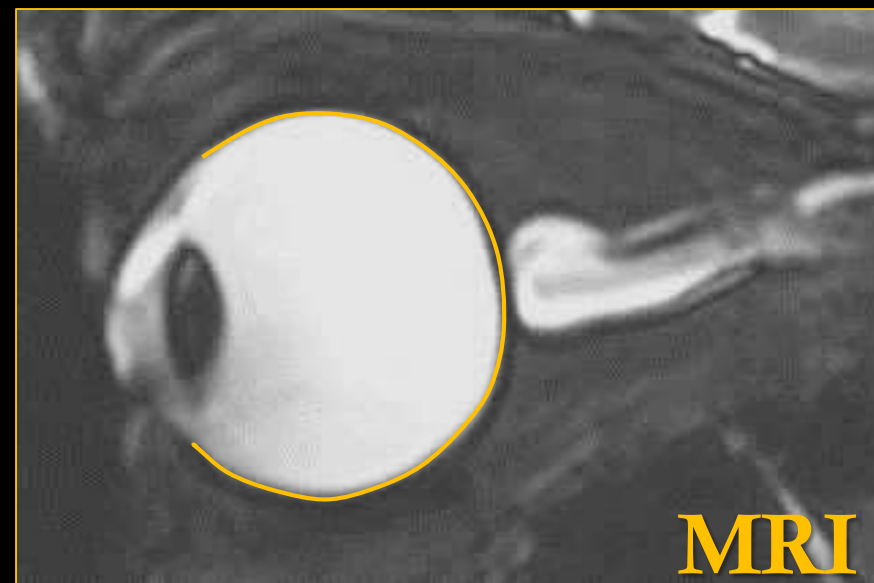


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- No meds
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w/ VO_2 max of 51ml/kg

- *Terrestrially*: Typically associated w/ increased intracranial pressure (e.g., IIH); typically bilateral



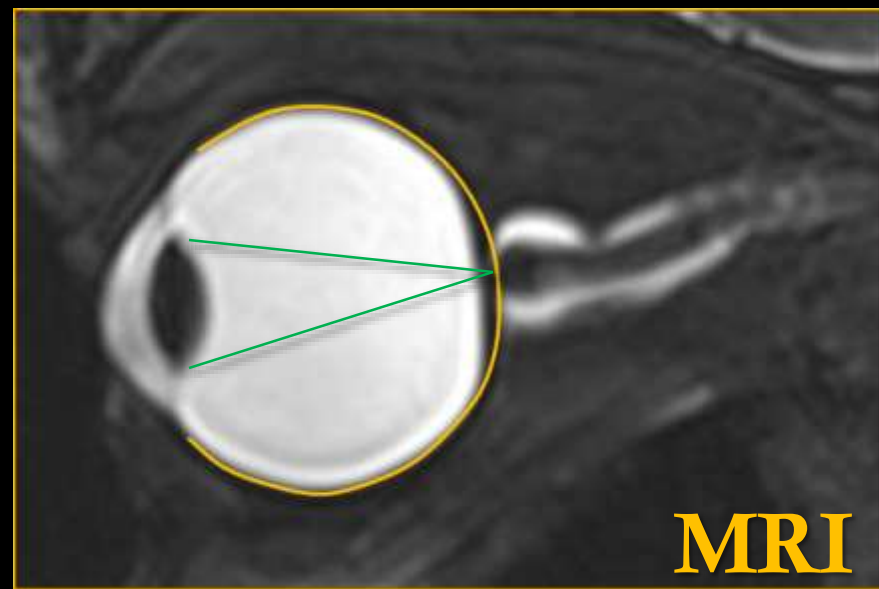
1 year post-flight



Clinical Findings: *Hyperopic Shift*



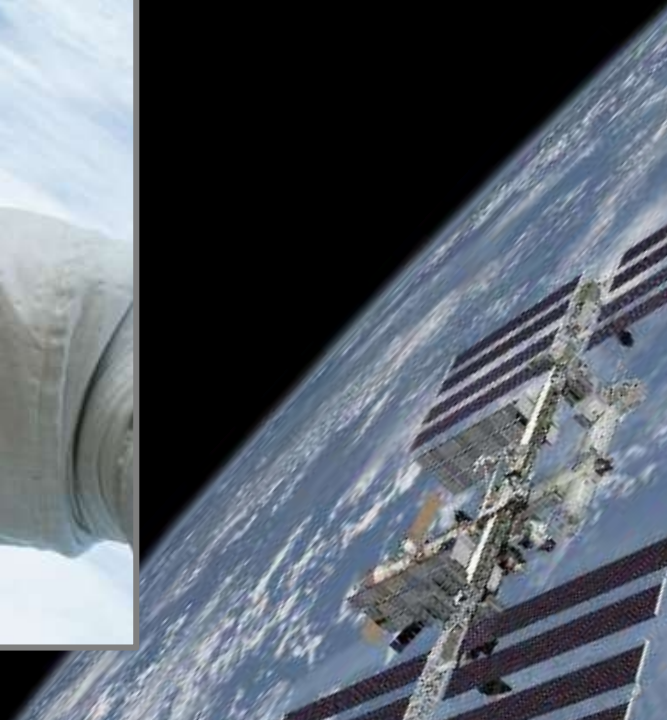
- Post-flight questionnaires (1989 - 2011): *23% of short- & 49% of long-duration mission astronauts report a **degradation in vision** (especially at **near distances**)*
 - Provided “Space Anticipation Glasses”
- *Mostly* attributable to globe flattening
- Pre-to-post-flight change
 - Up to +1.75D
 - Like globe flattening, can rebound or persist (7+ years)
- *No loss in BCVA* (i.e., 20/20 or better)



6 days post-flight



Common Characteristics of the Cases





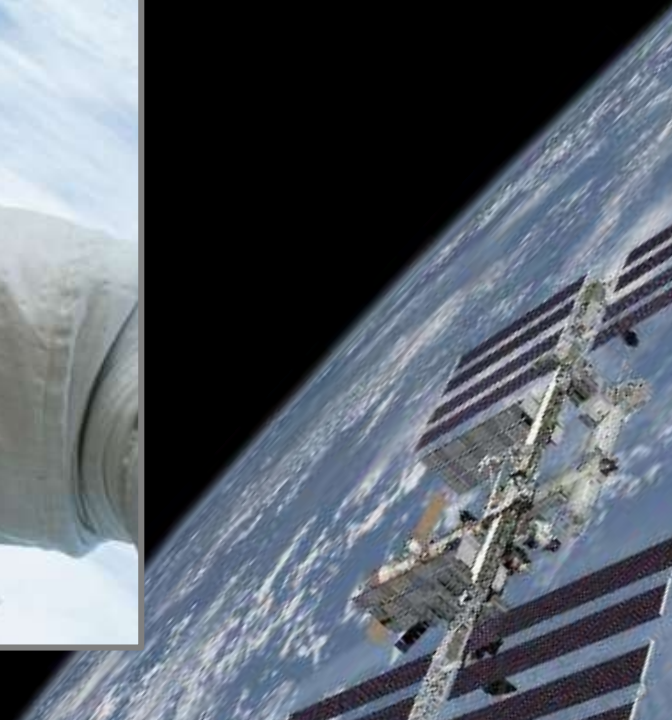
Common Characteristics of the Cases



- Almost all were long duration ISS mission crewmembers
 - *Is severity related to flight duration??* [If so, what about a *3-yr Mars mission??*]
- Healthy individuals w/ normal medical history & normal pre-flight eye exams
 - Negative for uncontrolled systemic disease
- ISS cabin
 - Elevated CO₂: **8-10x terrestrial levels** (~0.33-0.5% avg)
 - CO₂ is a potent vasodilator – *A potential SANS contributor??*
- None experienced loss in visual performance (e.g., BCVA, color vision, or depth perception)
- None complained of classic symptoms of idiopathic intracranial hypertension (IIH)
(e.g., Severe headaches, transient vision loss/obscurations, double vision, pulsatile tinnitus, etc.)
- Tendency for SANS signs to be right-hand biased



Why is this Happening?





Why is this Happening?



Microgravity → Cephalad fluid shift → Cerebral venous congestion (i.e., overfilling & distension)

Confounding variables: Resistive exercise /
Sodium intake / CO₂ levels / Pharmaceuticals??



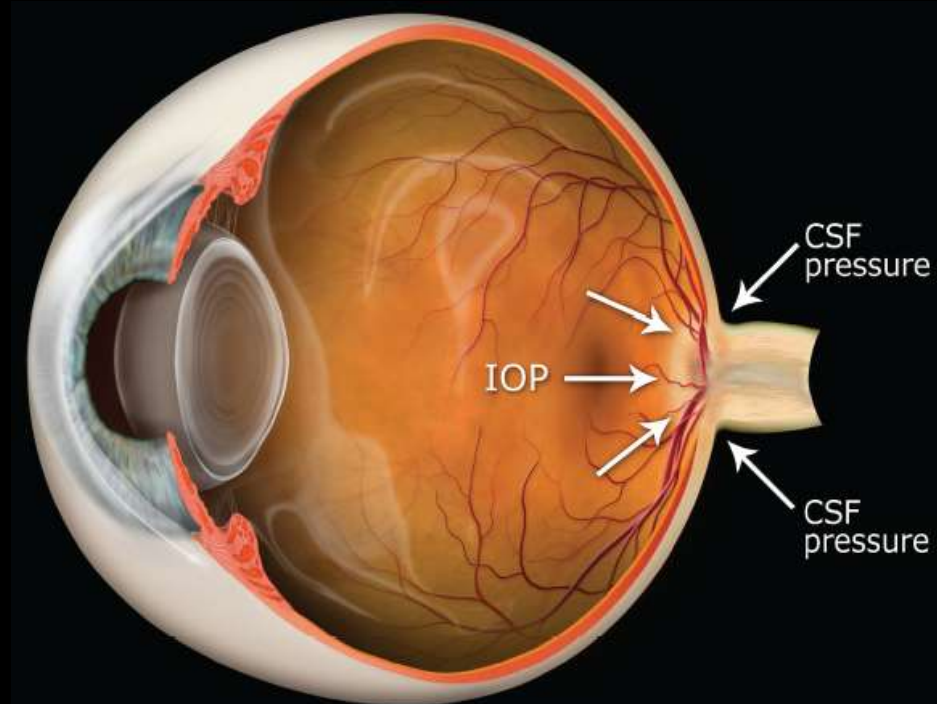
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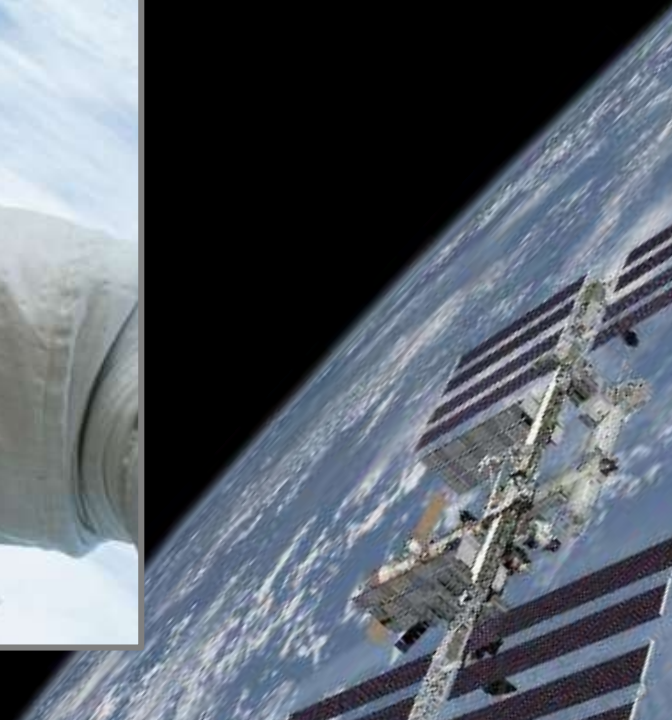
Confounding variables: Resistive exercise / Sodium intake / CO₂ levels / Pharmaceuticals??

- Hypothesis #1: *Increased intracranial pressure* (ICP)
 - e.g., Enough to cause an imbalance between ICP & intraocular pressure (i.e., translaminar pressure gradient)
- Hypothesis #2: *A local eye problem*
 - e.g., Compartmentalization of perioptic subarchnoid spaces → local increase in ICP
- Hypothesis #3: *Venous congestion* alters local physiology and/or places direct pressure on retinal axons
- Hypothesis #4: *Individual anatomical/genetic factors*
 - e.g., Altered folate-dependent 1-carbon metabolism





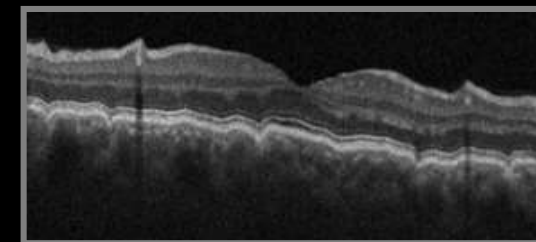
Take-Home Messages





Take-Home Messages

- **Top SANS-related risk: Optic disc edema**
 - Part of CNS – Susceptible to permanent loss, depending on severity & duration
 - Currently, no evidence of true vision impairment in long-duration astronauts
 - Most/all ISS astronauts have ocular “changes” in-flight, including disc edema
 - Cannot yet predict impact of SANS during expeditionary spaceflight
- **Choroidal folds, if under fovea, also pose a mission risk**
 - Could potentially decrease best-corrected VA to 20/40 – 20/60
- **Small sample sizes & confounding variables hamper definitive conclusions**
- **There are potential opportunities for win-win DoD/NASA collaborations**
 - Details / Fellowships / Clerkships / Research ??
 - Dozens of NASA projects that could benefit from aerospace physiologist expertise & experience, especially those w/ a research-based PhD





Questions?



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Email: Tyson.J.Brunstetter@nasa.gov

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