



# Visual Impairment Intracranial Pressure (VIIP) [aka Microgravity Ocular Syndrome (MOS)]

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# Why We Do What We Do...





# Recent VIIP/MOS Headlines:

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

**... 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



*Health & Science*  
**The mysterious syndrome impairing astronauts' sight**

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

**Astronauts Returning to Earth With Vision Problems**



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

POST ORIGINALS · July 5, 2016

A mission to  
Credit: ESA

ast  
e vision



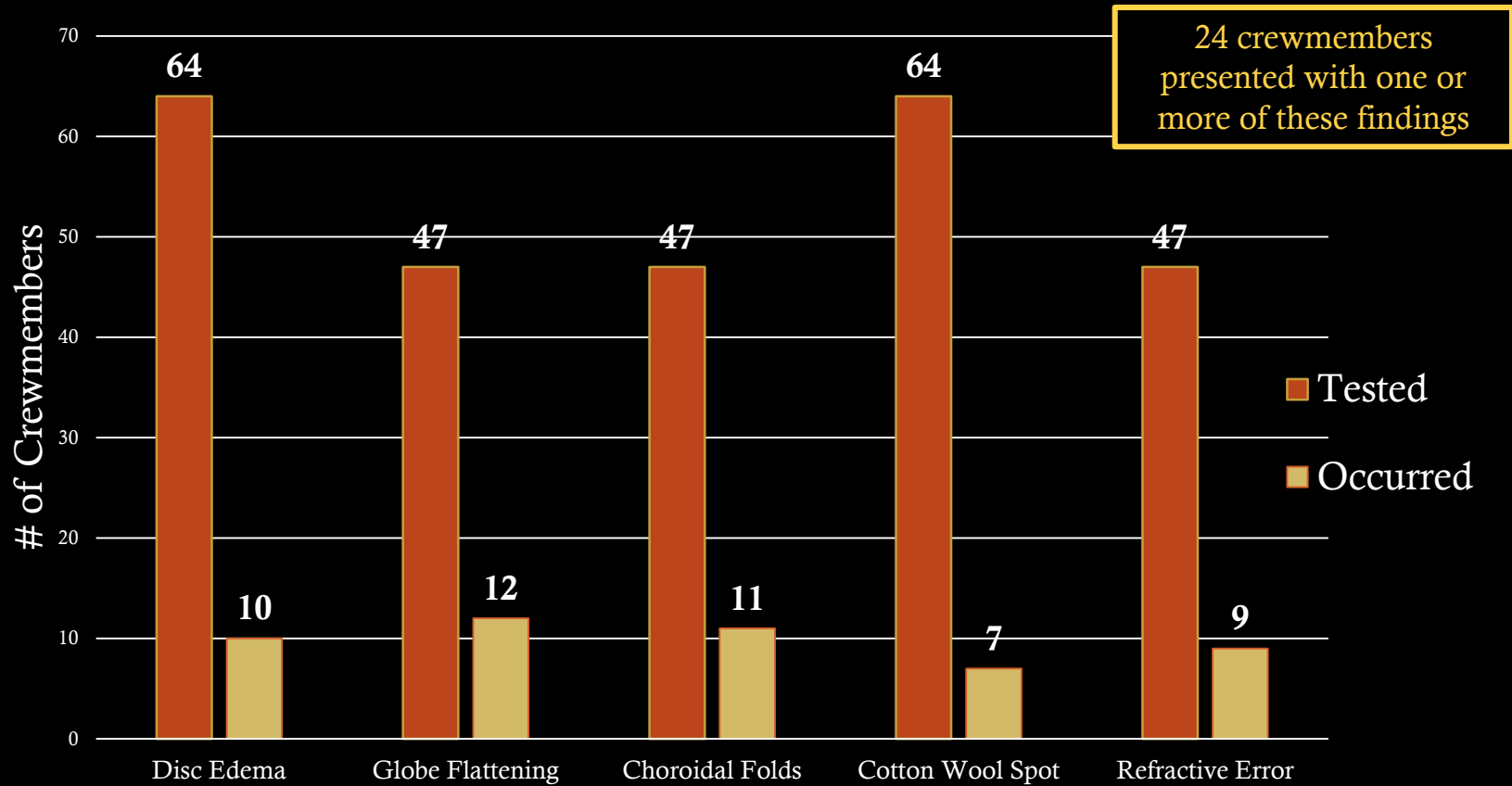
# VIIP/MOS: Clinical Findings

To date, 24 USOS ISS long-duration spaceflight astronauts have developed some or all of the following findings:

- Ocular* {
  - Hyperopic shift
  - Globe flattening
  - Choroidal folds
  - Cotton wool spots
  - Optic disc edema
  - Optic Nerve Sheath Distention} *ALL are potential signs of elevated intracranial pressure (ICP)*
- Mildly elevated post-flight intracranial pressure
  - 21 - 29 cm H<sub>2</sub>O range
    - Upper limit of normal: ~20 cm H<sub>2</sub>O
    - Gray zone: 20.1 – 24.9 cm H<sub>2</sub>O



# USOS Individuals w/ VIIP/MOS Findings: Expeditions 1-48



❖ Disc Edema = Modified Frisen Scale Grade  $\geq 1$  at first post-flight eye exam (via fundoscopy)

❖ Globe Flattening = A change compared to preflight (via MRI or ultrasound)

❖ Choroidal Folds = New or worsened compared to pre-flight (via OCT)

❖ Cotton Wool Spot = Presence in-flight or post-flight (via fundoscopy)

❖ Refractive Error = Change in cycloplegic (spherical) refraction  $\geq 0.75D$  from preflight to first post-flight eye exam



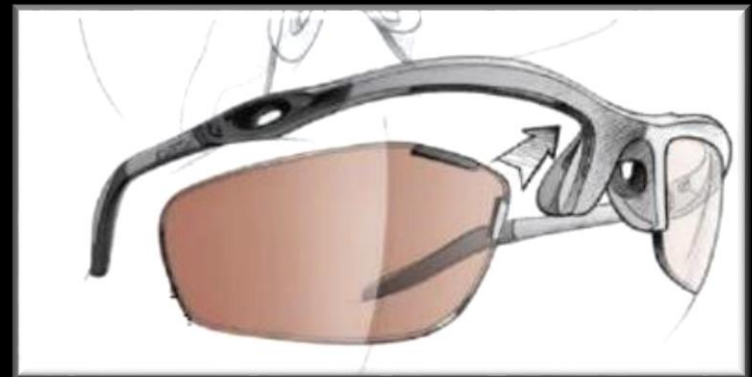
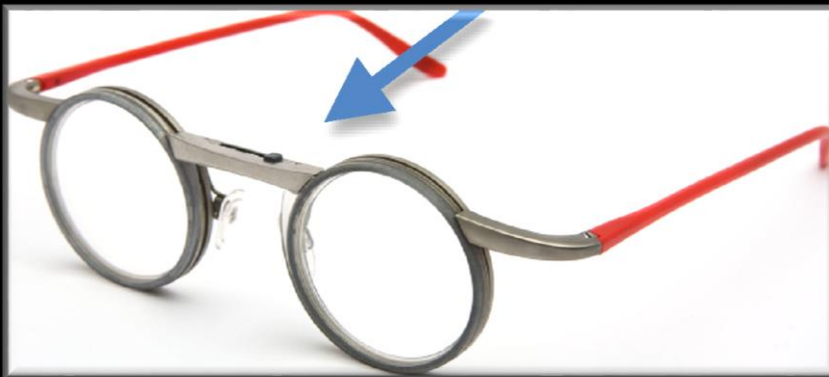
# VIIP/MOS Clinical Findings





# Clinical Findings: *Hyperopic Shift*

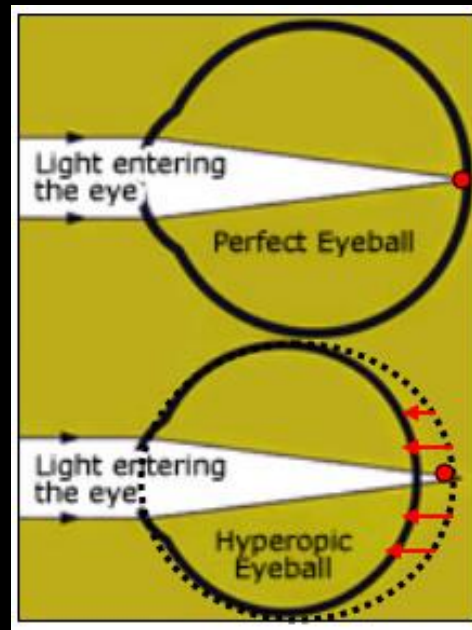
- Of the active astronaut population...
  - 80% wear vision correction (32% contact lenses)
  - Mean age = 47 yrs
  - Majority are presbyopic (i.e., a normal, age-related, progressively worsening inability to focus clearly on near objects)
- From postflight questionnaires (1989 - 2011): *25% of short-duration (Shuttle) & 50% of long- duration (ISS) mission astronauts report a **subjective degradation in vision**, especially at near*
  - Provided “Space Anticipation Glasses”





# Clinical Findings: *Hyperopic Shift*

- Subjective Degradation in Vision (cont):
  - Associated w/ *Hyperopic Shifts* in refractive error due to *Globe Flattening*
    - A 1 mm decrease in axial length will produce a ~3 diopter hyperopic shift
    - Largest shift to date is +1.75 diopters
    - In presbyopes: Typically decreases near visual acuity (VA), but leaves distant VA intact



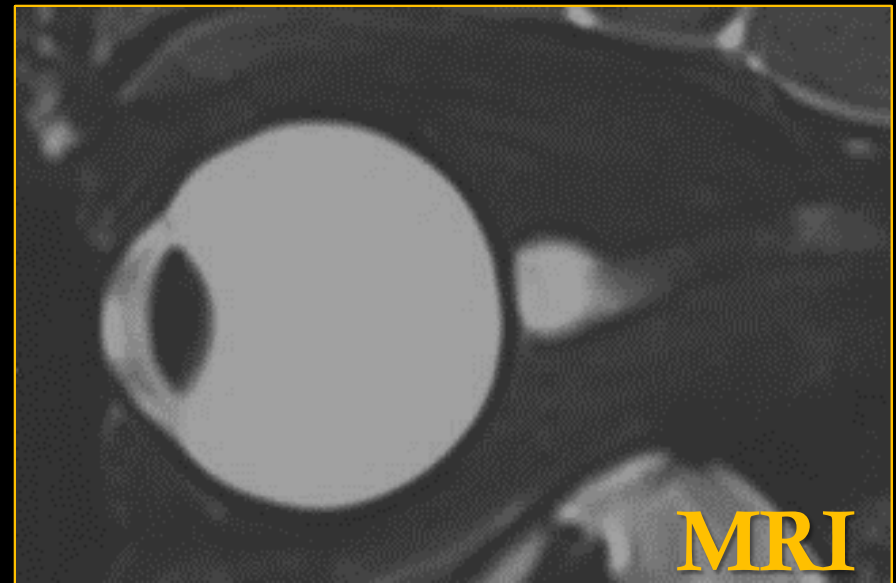




# Clinical Findings: *Globe Flattening*

- 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

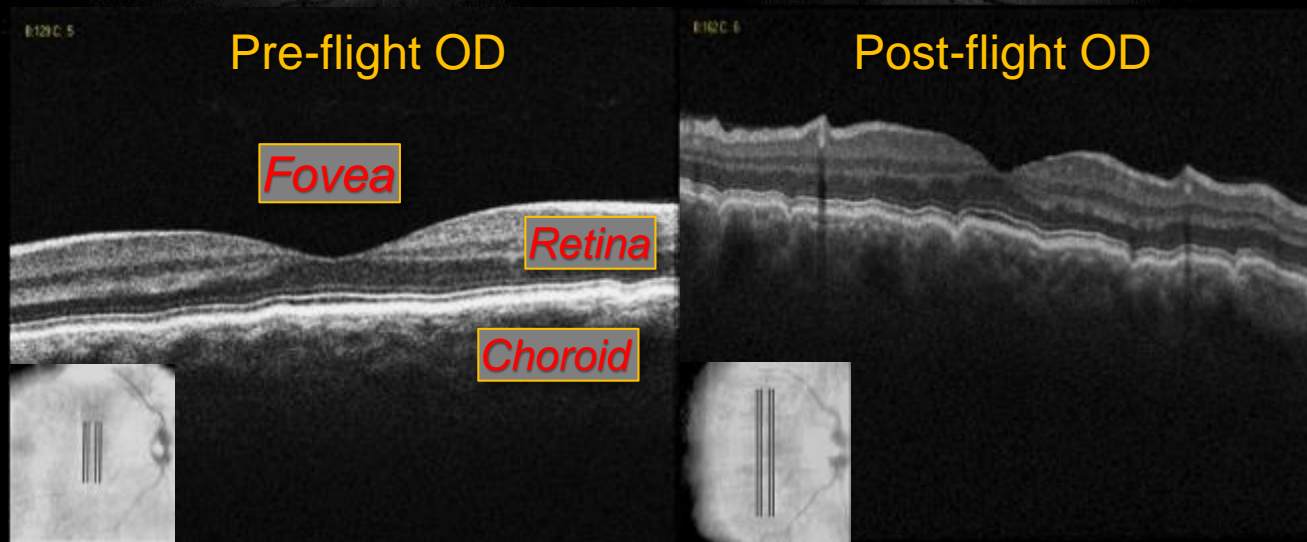
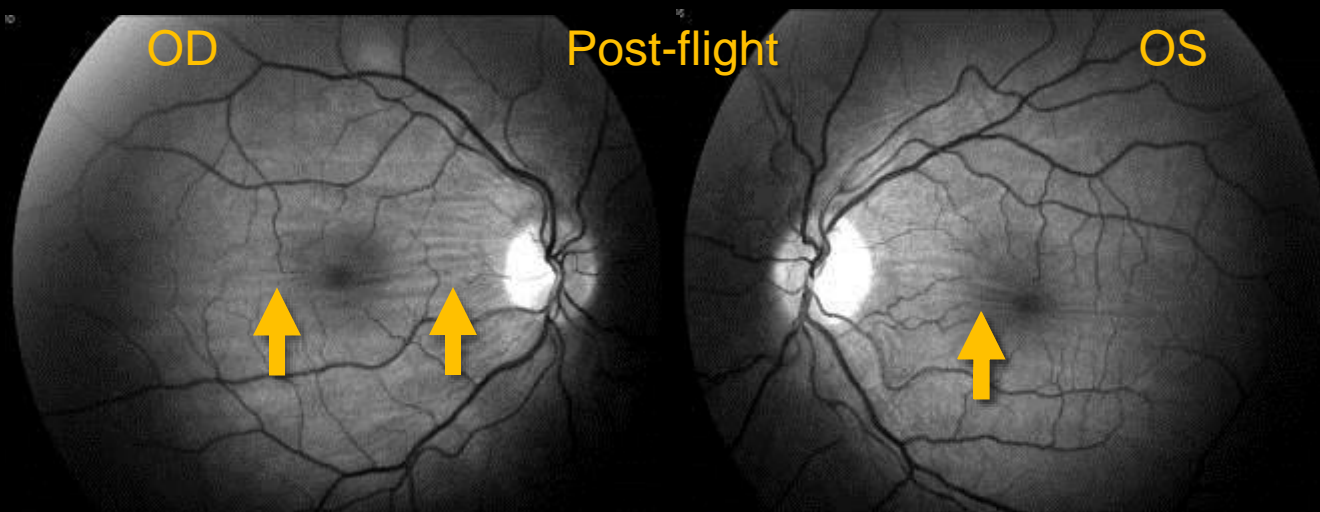
- *Terrestrially*: Globe flattening associated w/ papilledema (i.e., disc edema 2° to increased intracranial pressure); typically bilateral



6 days post-flight



# Clinical Findings: *Choroidal Folds*



- Choroidal thickening due to vessel engorgement
- Induces choroidal and retinal folds
- Can resolve post-flight or can persist for 5+ yrs
- So far, no clinically-significant impact on BCVA
- *Terrestrially: Assoc. w/ choroidal tumors, scleritis, retrobulbar mass, papilledema/IIH*



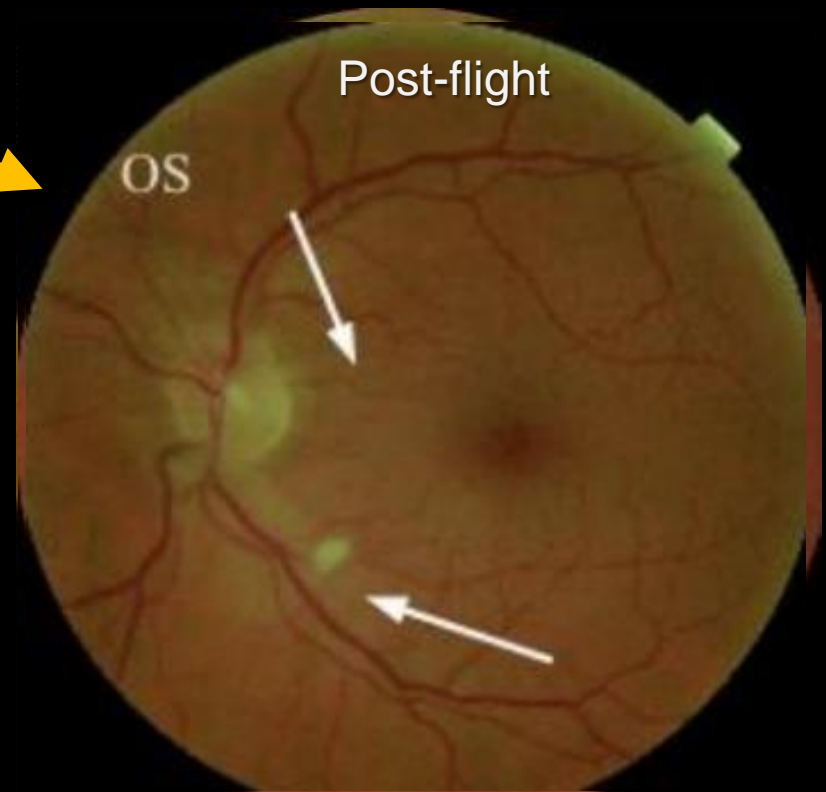
# Clinical Findings: *Cotton Wool Spots*

Posterior pole fundoscopic images  
OD & OS for two ISS crewmembers

- Top arrows: **Choroidal folds**
- Bottom arrows: **Cotton wool spots**

- Cotton wools spots
  - Abnormal retinal finding
  - Accumulations of axoplasmic material w/in retinal nerve fiber layer
  - Caused by ischemia → reduced axonal transport → swelling of axon → damaged nerve fibers
  - *Terrestrially: Associated w/ diabetes, HTN, central retinal vein occlusion*

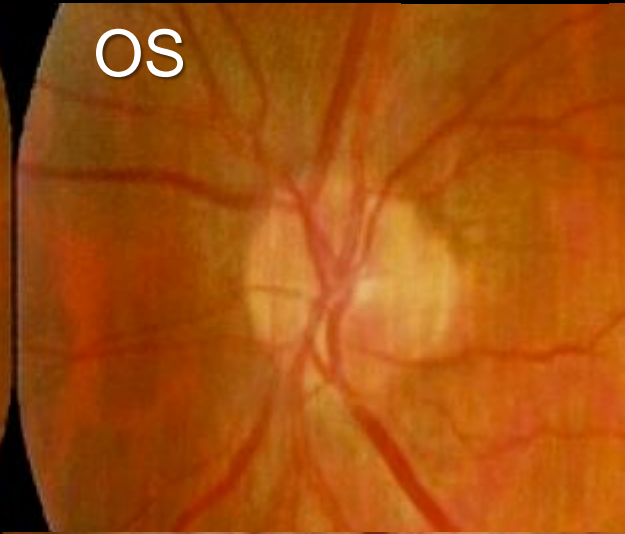
*Example 1*



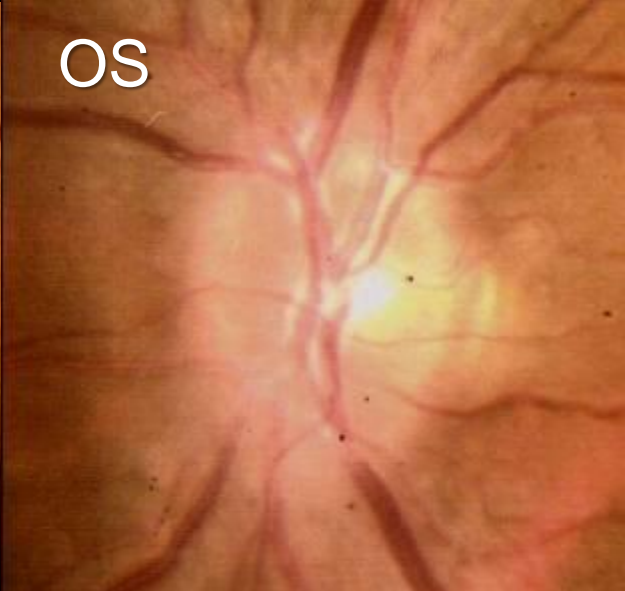


# Clinical Findings: *Optic Disc Edema*

**Pre-flight** fundoscopic images of the right (OD) & left (OS) optic discs



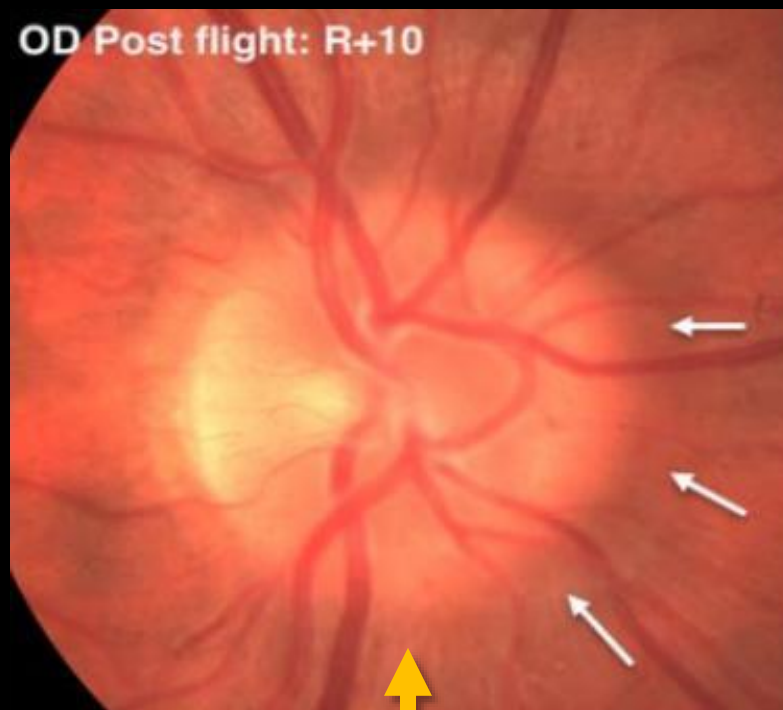
**Post-flight** images of optic discs, showing *Grade 3 edema OD & Grade 1 edema OS*





# Clinical Findings: *Optic Disc Edema*

- *Terrestrially*: Optic disc edema is associated with:
  - Unilateral: Optic neuritis, optic neuropathy, retinal artery/vein occlusion
  - Bilateral: Increase in ICP...
    - IIH (→ “papilledema”)
    - Intracranial mass
    - Cerebral edema
    - Increased CSF production
    - Decreased CSF absorption
    - Obstructive hydrocephalus
    - Venous outflow obstruction
  - Typically reduces VA, enlarges blind spot, causes relative afferent pupillary defect & color impairment



Fundoscopic image of optic disc OD,  
10 days after return to Earth

- Arrows: “C” shaped halo of edema

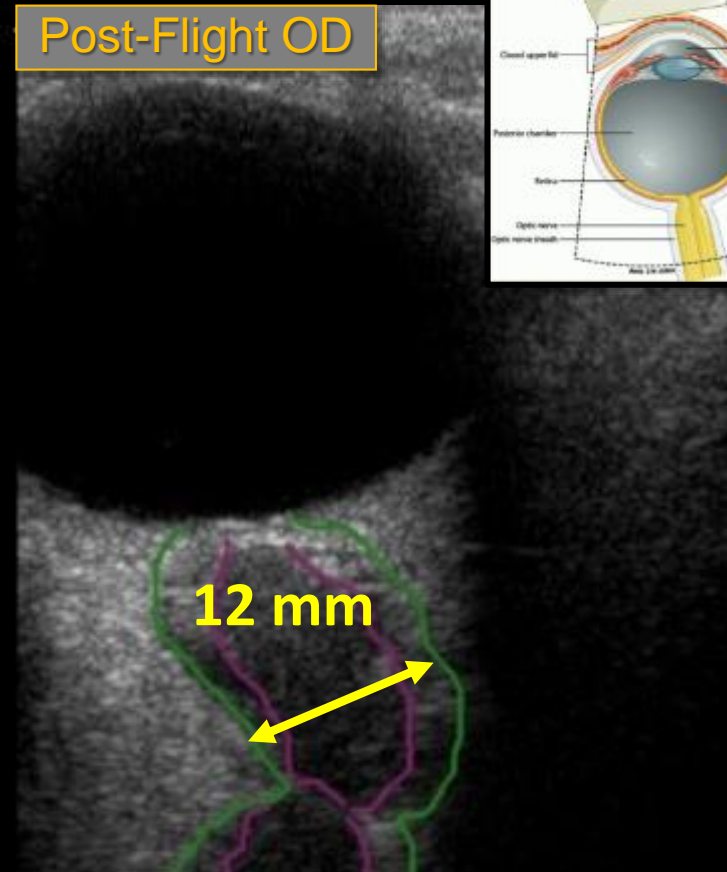


# Clinical Findings: *Optic Nerve Sheath Δs*

Post-flight ultrasound image of globe, optic nerve (ON; purple), and optic nerve sheath (green). Showing:

- ON Sheath distention
- ON tortuosity

Post-Flight OD



- **ON Sheath *terrestrially*:**
  - Normal diameter (ONSD) < 5.9 mm
  - Enlargement typically associated w/ increased ICP



# Common Characteristics of the Cases





# Common Characteristics of the Cases

- ~6 month duration ISS mission
  - [No clinically-significant signs during short-duration flights]
  - Dose response??
- All had normal pre-flight eye exams
- Past medical history:
  - Negative for systemic disease
  - None had used medications before/during their mission that could increase ICP (e.g., vitamin A, tetracycline, corticosteroids, or nalidixic acid)

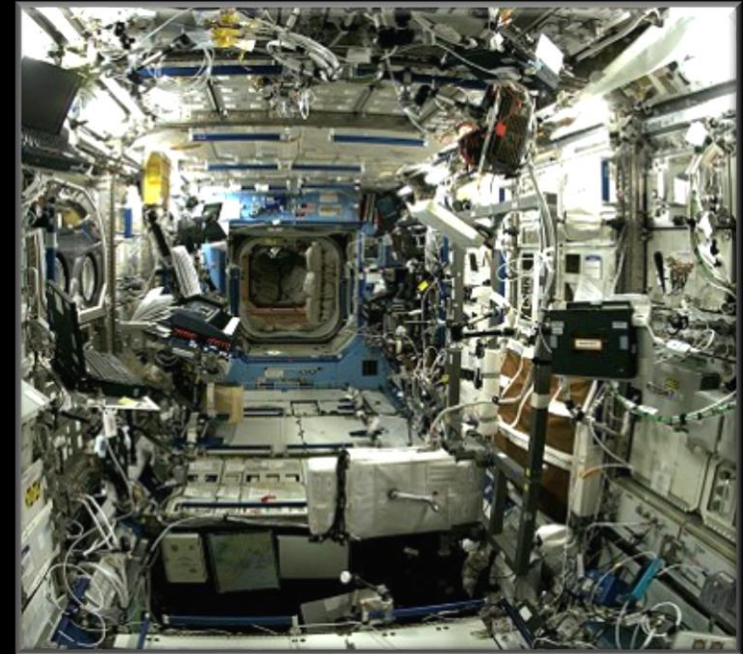






# Common Characteristics of the Cases

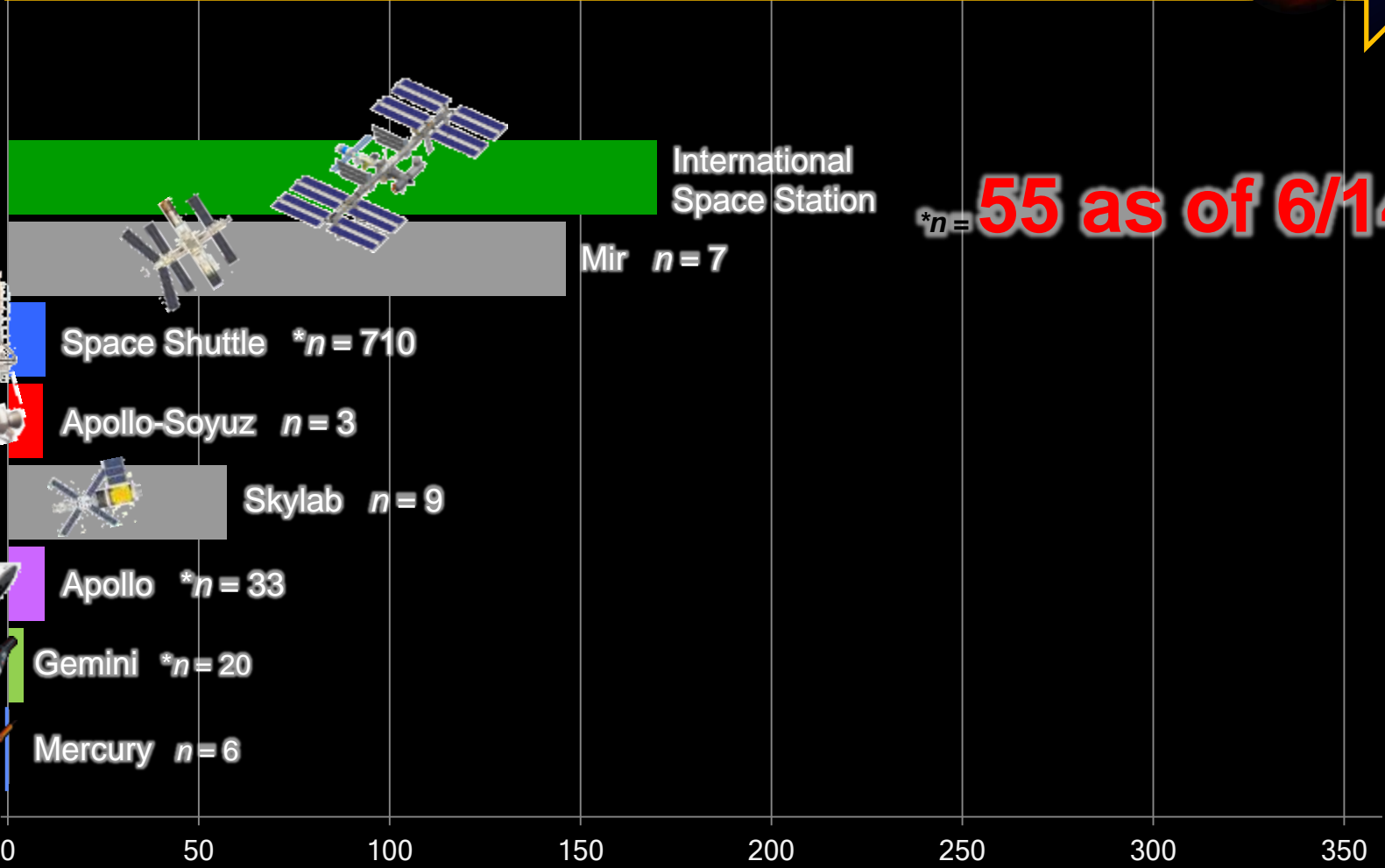
- None complained of headaches, transient vision loss, double vision, pulsatile tinnitus, or vision changes during eye mvmts (i.e., the classic symptoms of idiopathic intracranial hypertension)
- None experienced loss in best-corrected visual acuity, color vision, or stereopsis
- Right eye affected more than left in all cases
- ISS cabin
  - Normal pressure & oxygen
  - Elevated CO<sub>2</sub>
    - ~0.33-0.5% avg, w/ avg peak ~0.7%
    - 10x terrestrially: ~0.03-0.04%





We are just entering, relatively speaking, the long-duration phase of space exposure...

# Next Generation Missions



Average Days

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



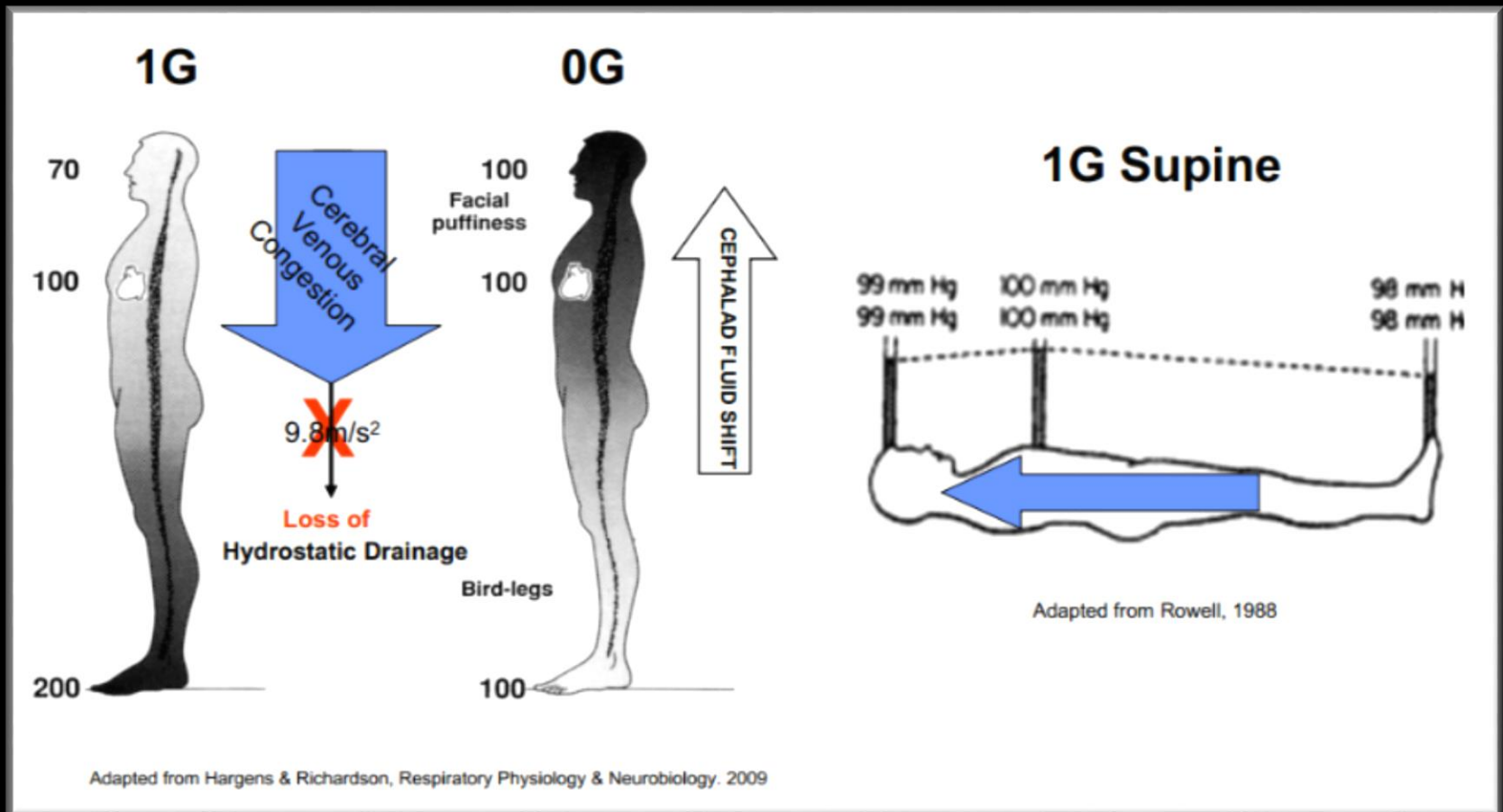
# Why is this Happening?





# Why is this Happening?

Microgravity → Cephalad fluid shift → Cerebral venous congestion



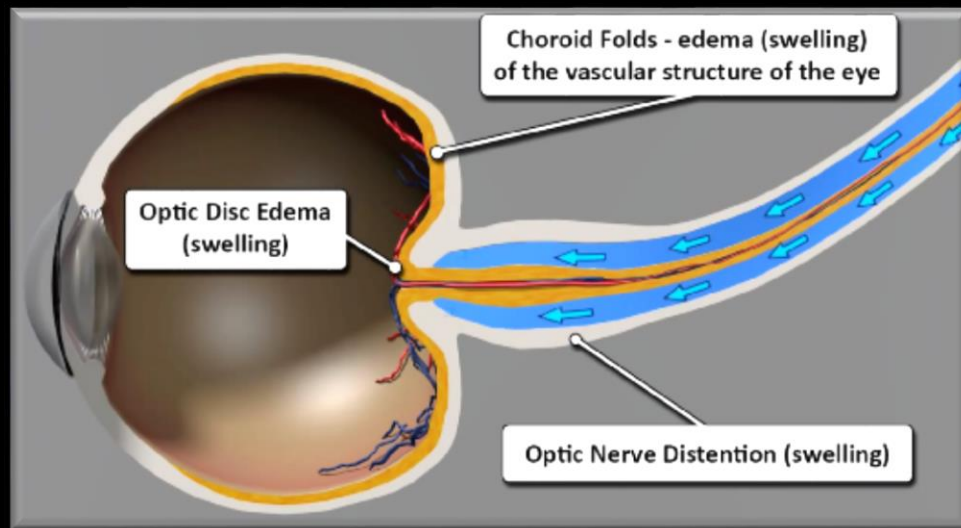


# Why is this Happening?

- Current Risk Statement:

## “Visual Impairment Intracranial Pressure” (VIIP)

“Given that the microgravity environment causes cephalad fluid shift in astronauts, there is a probability that astronauts will have intracranial hypertension (IHT) to some degree, which if left untreated, could lead to deleterious health effects.”





# Why is this Happening?

- Hypothesis #1: **Increased intracranial pressure**
  - The original theory, hence the name “Visual Impairment Intracranial Pressure”
- Hypothesis #2: **This is a local ocular eye problem**
- Hypothesis #3: **Slight IOP reduction + slight ICP increase**
- Hypothesis #4: **Folate-dependent 1-carbon metabolic pathway altered**
- Hypothesis #5: **Vessel congestion placing pressure locally around optic nerve (“Circle of Zinn-Haller” theory)**
  - In  $\mu$ Gravity, head venous pressure  $\approx$  15-20 mmHg
    - Standing terrestrially  $\approx$  -20 mmHg



# In-flight Exacerbating Factors??

## Resistive Exercise



## High Oral Sodium Intake

Prepackaged Foods...  
Up to 5000+ mg/day



High CO<sub>2</sub>  
~10x terrestrial levels



## In-flight Pharmaceuticals





# Medical Surveillance







# Surveillance & Medical Data Collection

- 49 ISS expedition missions have been completed (since 2000)
- Sentinel case occurred in 2005
  - Optic disc edema and cotton wool spot
- Surveillance/medical data collection is ongoing and has evolved
  - Began *some* “VIIP” related testing in 2008 (w/ Exp 18)
  - Inconsistent testing until Feb 2010 (Exp 23) when Eye MED B came into effect





# Surveillance & Medical Data Collection

## Terrestrially

- 3T MRI – Special “NASA Astronaut” protocol 12-18 months prior to launch

## Terrestrially & On-Orbit

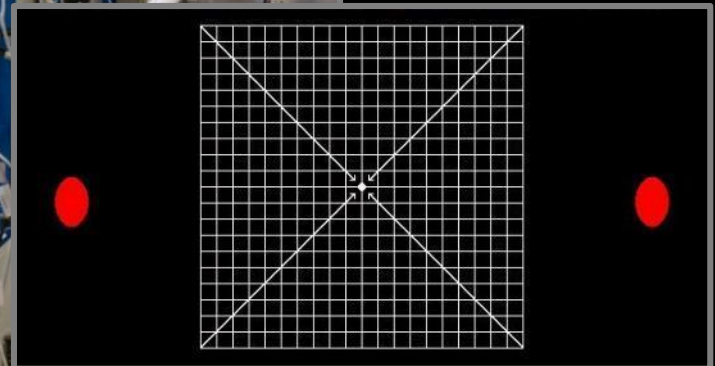
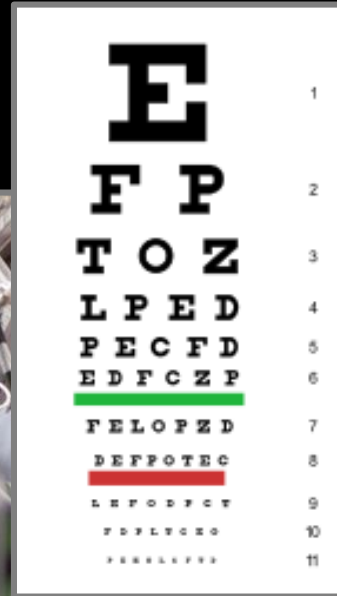
- Vision Exam
  - Visual Acuity (near & far)
  - Amsler grid
- Ocular Ultrasound
- Fundoscopy
- Optical Coherence Tomography (OCT)
- Tonometry (when clinically indicated)





# Surveillance & Medical Data Collection

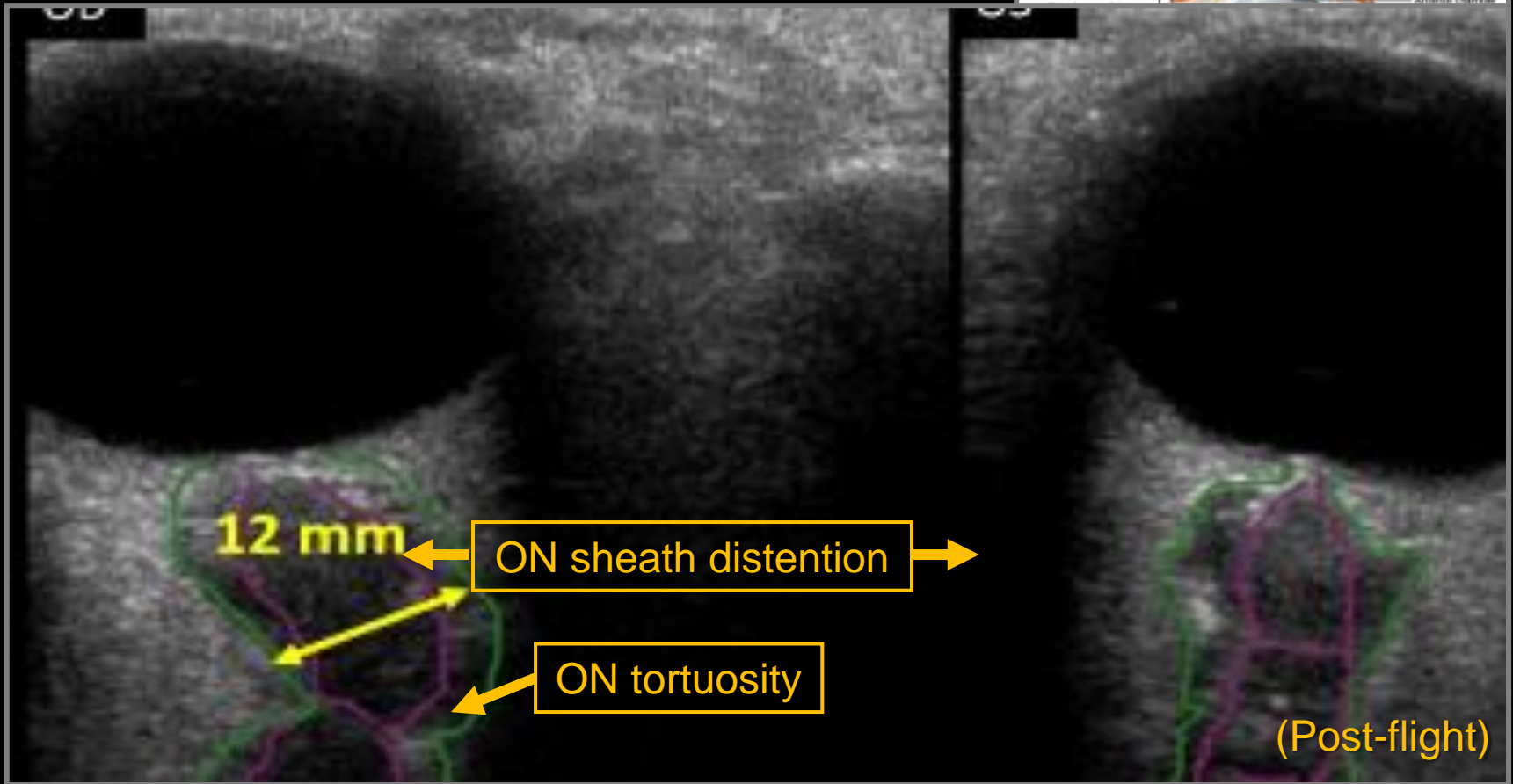
## Visual Acuity & Amsler Grid





# Surveillance & Medical Data Collection

## On-orbit Ultrasound Imaging





# Surveillance & Medical Data Collection

## Fundoscope





# Surveillance & Medical Data Collection

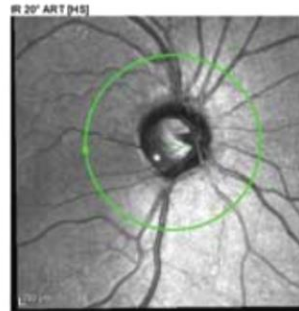
## Optical Coherence Tomography (OCT)



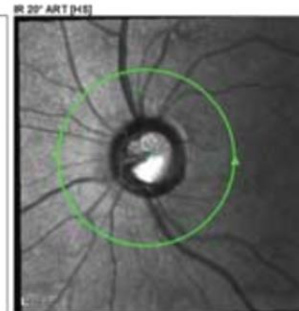
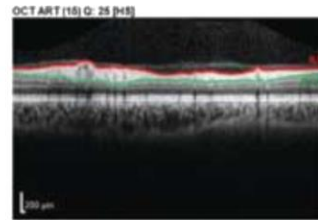


OD

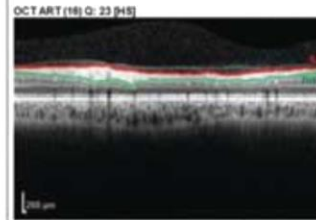
A



Asymmetry  
OD - OS

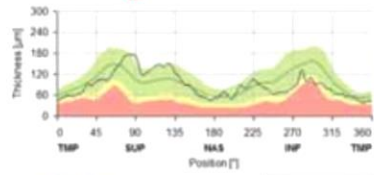


OS

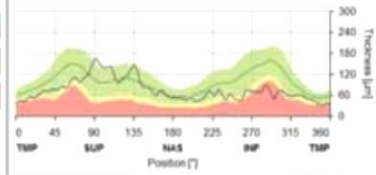


**Note:**  
Representative  
OCT report;  
Not actual  
astronaut data

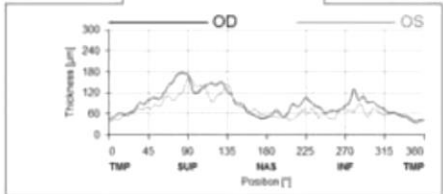
B



Within Normal Limits (p>0.05)  
Borderline (p<0.05)  
Outside Normal Limits (p<0.01)



C



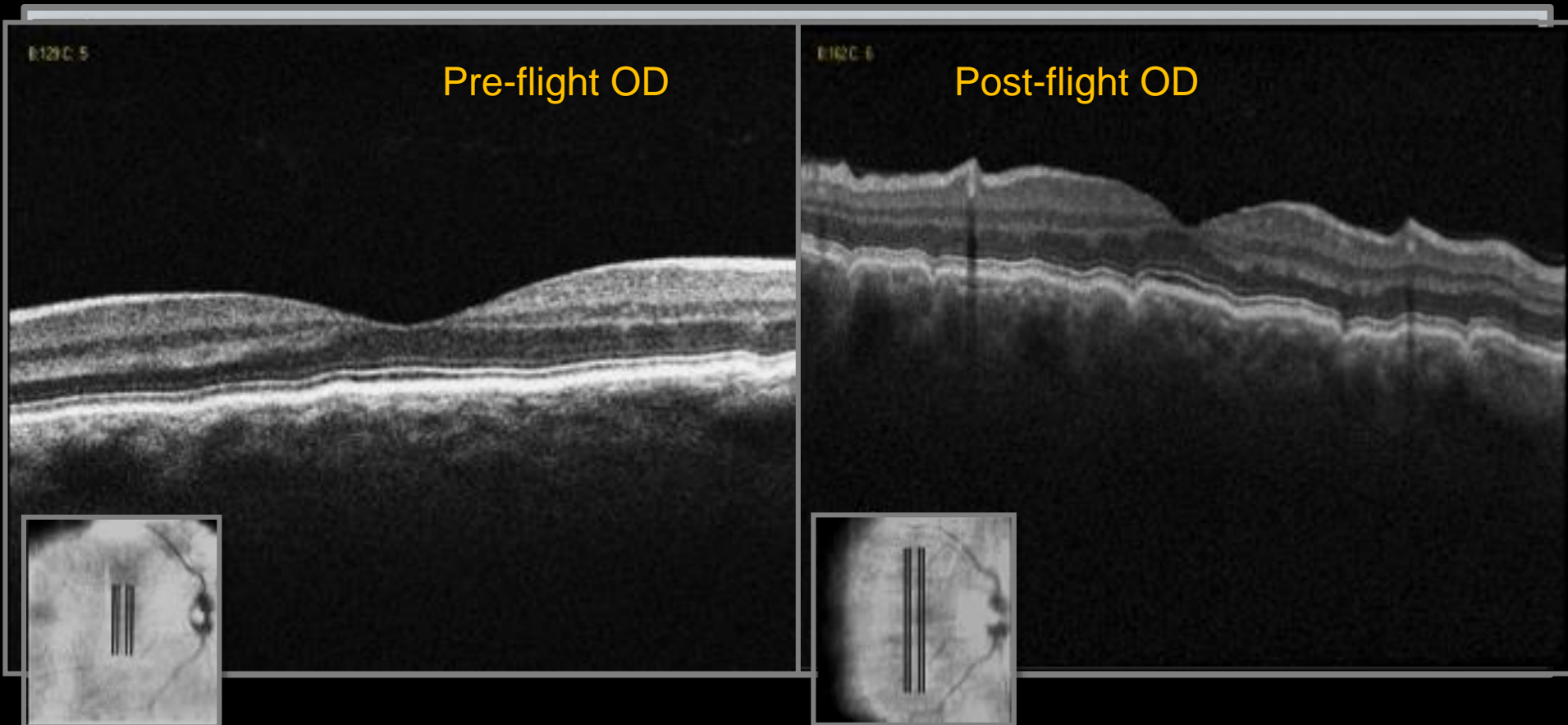
1 mm





# Surveillance & Medical Data Collection

## Optical Coherence Tomography (OCT)





# Clinical & Research Update

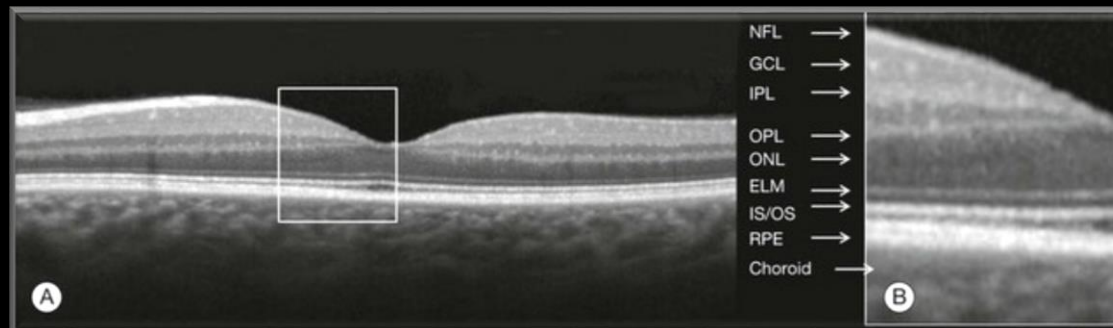




# Clinical Update: Feb17

## *Ongoing clinical work*

- Correlation between ocular structural changes (OCT) and chronic effect on visual function (visual fields testing)
- Correlation of subcortical white matter hyperintensities (WMH) found on MRI and VIIP/MOS signs – 2017
- Refinement of cardiovascular parameters and their correlation with VIIP/MOS signs – 2017
- We are evaluating the next generation OCT, “OCT2” to determine if it will enhance on orbit imaging/data acquisition





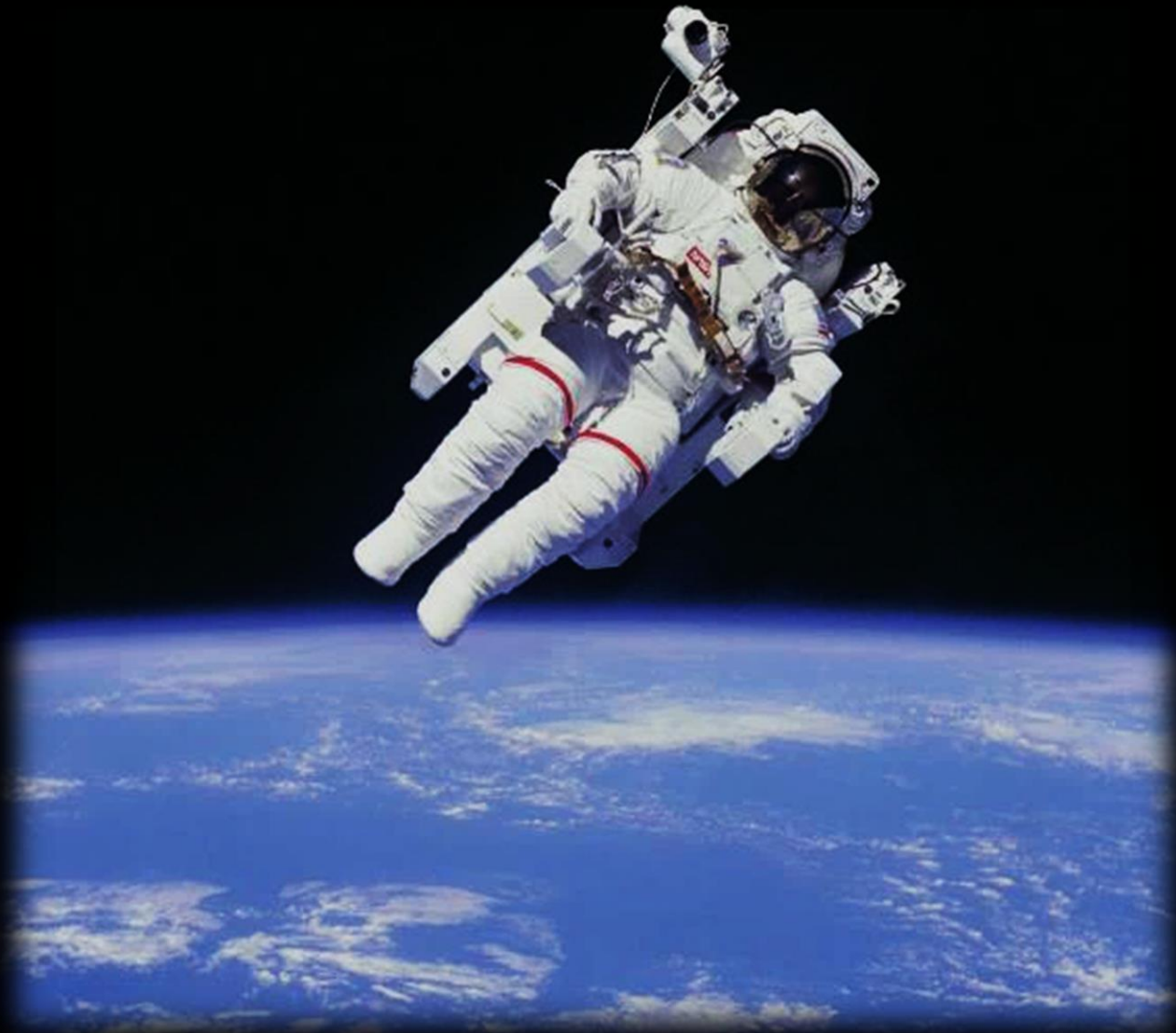
# What We Are Watching Coming From Our Research Colleagues

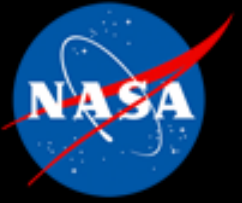
- Ocular Health Study and the Fluid Shifts Study – both finish data collection this summer
- Clinical relevance of MRI-based findings
- Implementation of direct ICP measures study pre and post mission
- Correlation between HDT with CO<sub>2</sub> and VIIP/MOS (EnviHab)





# Questions?



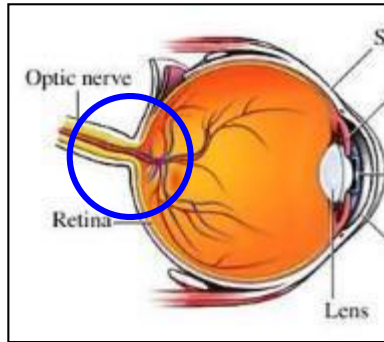


Back-Up



# The Lamina Cribosa & the Translaminar Pressure Gradient: A Mechanism for Papilledema

Area of Interest:



Translaminar Pressure Gradients:

