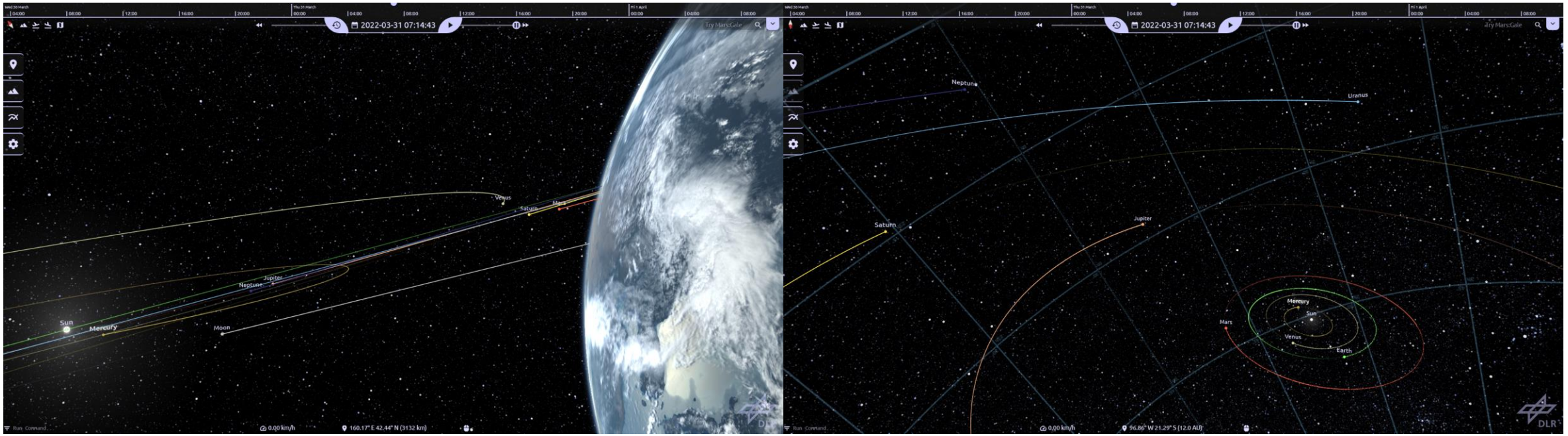
Motion Sickness Reduction for 6-DoF-Navigation in a Virtual Solar System

What is CosmoScout VR?

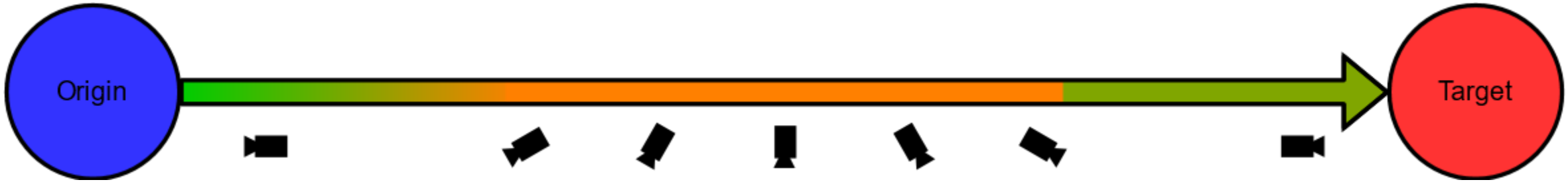
- Virtual Reality Simulation of our solar system
- High resolution elevation models and satellite imagery
- Real-time exploration of entire planets and space missions
- Scientific Visualisation of Data in VR



What Problems Do I Want To Fix?

- 6 DoF Navigation Controls with remote lead to complex rotations in free movement
  - Disorientation increases likelihood of motion sickness

- Automatic Navigation uses simultaneous translation and rotation during travel path
  - Quick rotation at peak speed may induce sickness symptoms
  - Occurs during bookmark navigation and landing/ascending animation



What Causes Motion Sickness?

Sensory Conflict Theory

- Information from user's senses conflict with each other or with the expectation in given context
- Sensory conflict due to vection though as one of the prime causes of cybersickness

Postural Instability Theory

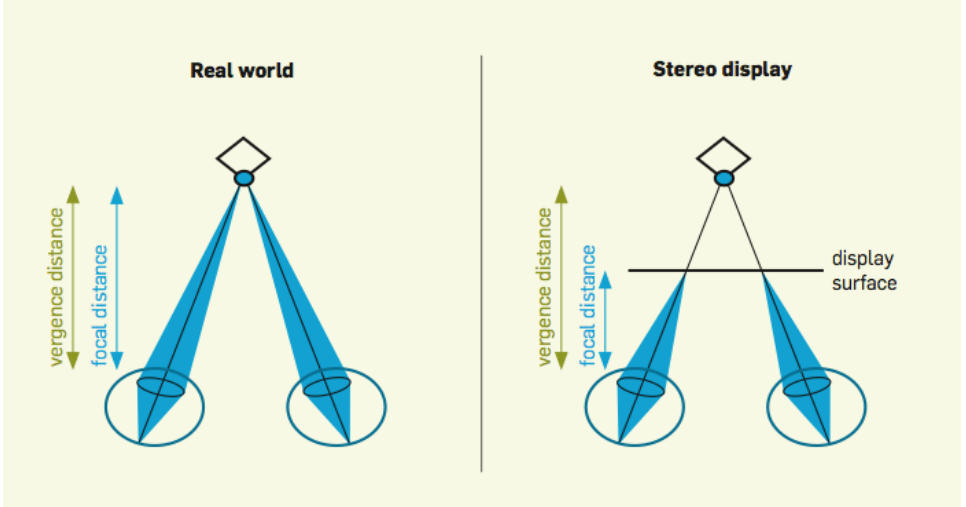
- State in which uncontrolled movements of the perception and action system happen
- Postural instability i.e., lateral-medial body sway often precedes experiences of motion sickness
- People who are naturally unstable seem to be more likely to become motion sick during VR

Saredakis D., Szpak A., Birckhead B., Keage H. A. D., Rizzo A., Loetscher T.:
Factors Associated With Virtual Reality Sickness in Head-Mounted Displays: A Systematic review and Meta-Analysis.
March 2020. https://doi.org/10.3389/fnhum.2020.00096

What Causes Motion Sickness?

Vergence-Accommodation Conflict Theory

- Vergence refers to lateral eye movement to adjust to objects moving towards or away from the user together with the process of focusing on the object (Accommodation)
- Process does not occur in stereoscopic displays, where accommodation occurs at fixed screen depth



Kroeker K. L.: *Looking beyond stereoscopic 3D's revival*. August 2010. https://doi.org/10.1145/1787234.1787241

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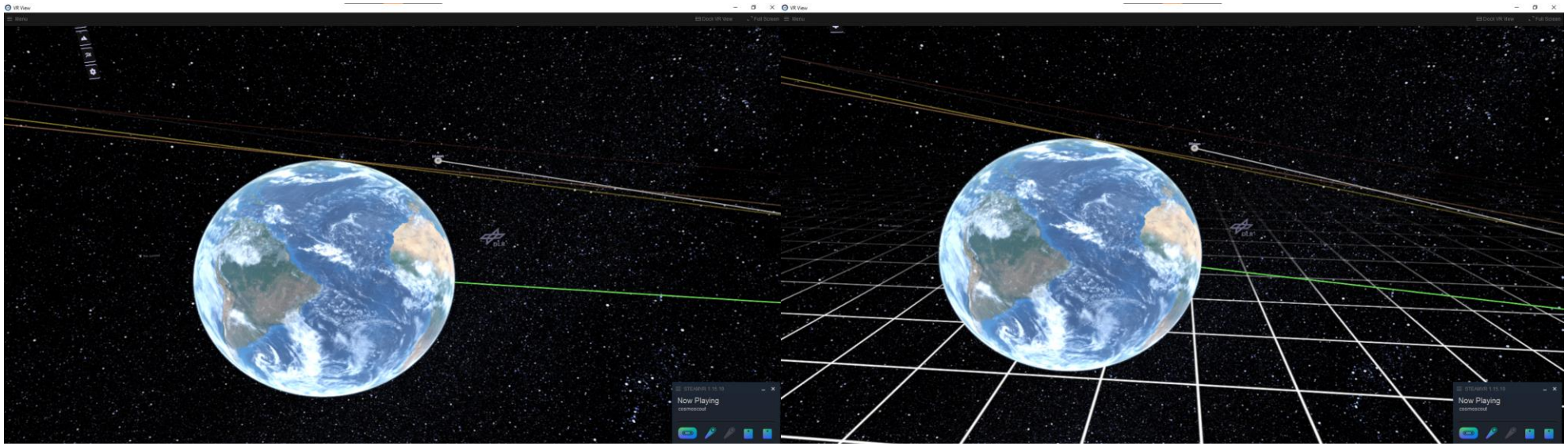
How To Mitigate The Problems? - Floor Grid

- Provides a stable simulated frame of reference during interplanetary free and automatic navigation
  - Assist with postural stability and sensory conflicts
- Change interaction context from Observer moving through the simulation to solar system being simulated and manipulated around the fixed user
  - Mitigates sensory conflict problems as the user is not moving, and VR orientation mirrors real-world situation

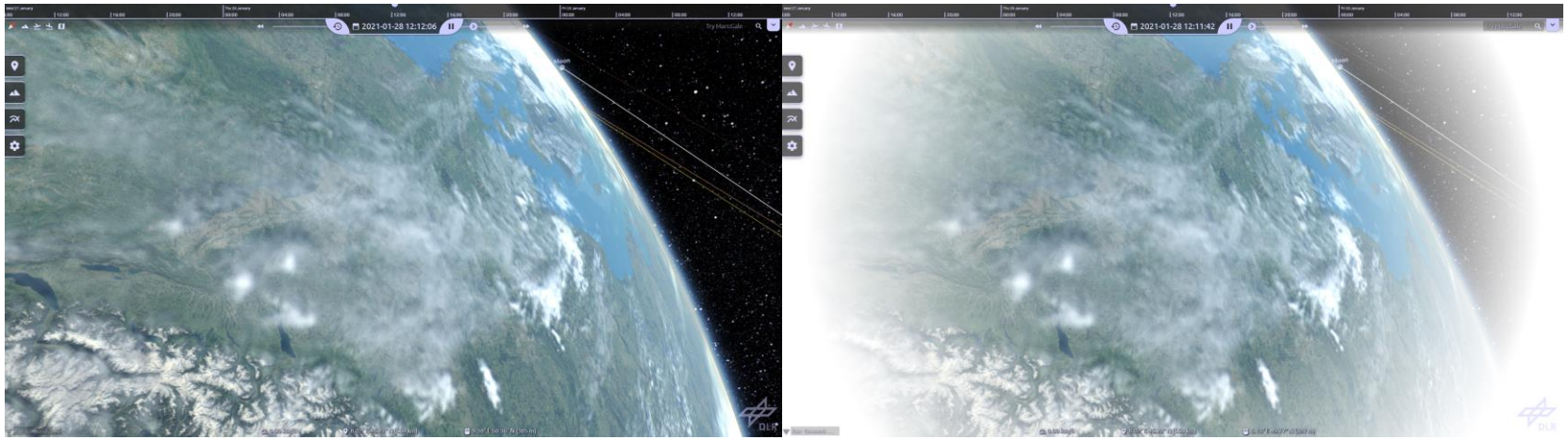


How To Mitigate The Problems? - FoV Vignette

- Popular method of cybersickness reduction
  - Applications with high detail and/or movement in peripheral areas of vision

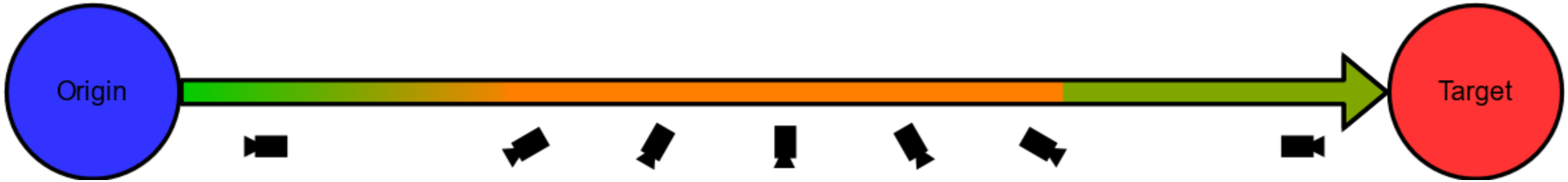
- User tends to react to High peripheral detail / movement by moving their eyes instead of their head
  - Employ vignette to limit users FoV, focusing on the centre of HMD lenses

- Post-Processing shader draws vignette radius according to movement speed



How To Mitigate The Problems? - Automatic Navigation Overhaul

- Orbit-to-Orbit Navigation
  - Travel between objects in interplanetary space
  - Travel in the orbit of an object
- Orbit-to-Surface Navigation
  - Travel to and from the surface to the standard orbit distance
- Surface-to-Surface Navigation
  - Travel between different location on the same body



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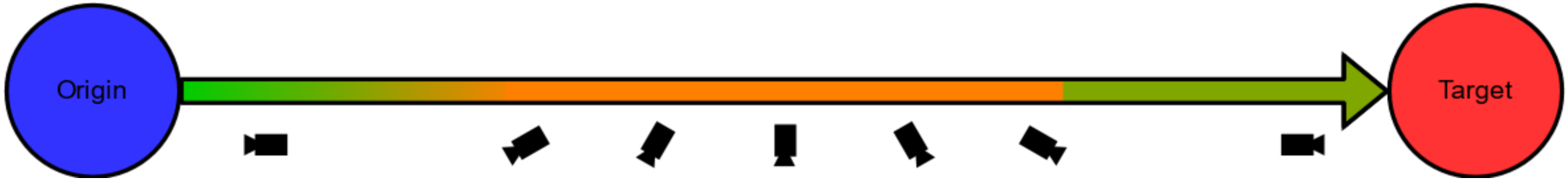
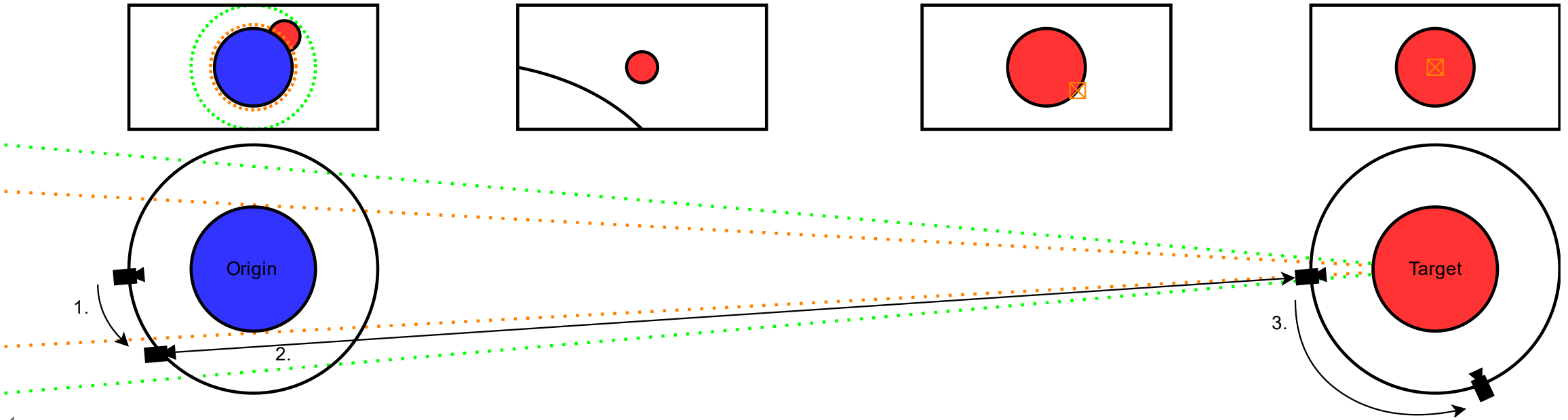
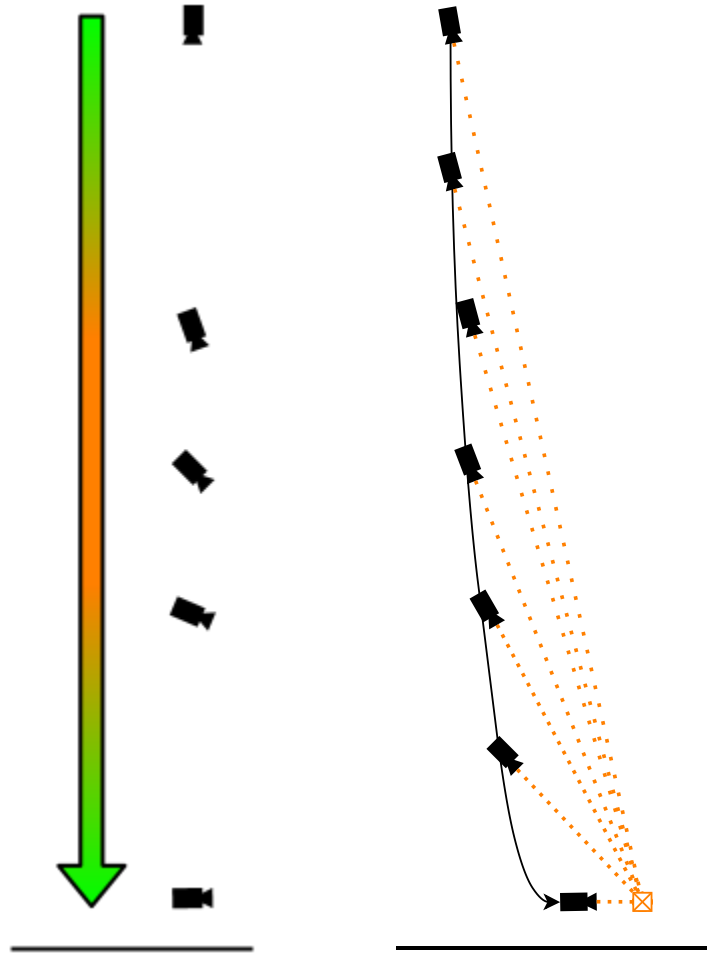




How To Mitigate The Problems? - Automatic Navigation Overhaul

- Travel paths moving the user forwards
  - Move in orbit over and rotate towards target
  - Lock view direction onto target's orientation and move along parabola curve down to target

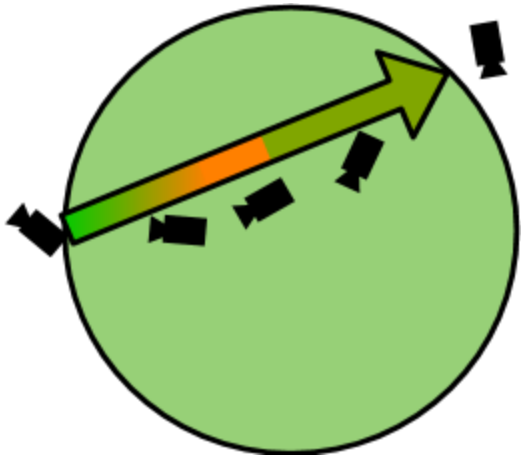
- Simple, predictable movements to mitigate sensory conflicts
- Parabola movement instead of linear to "move into" target orientation

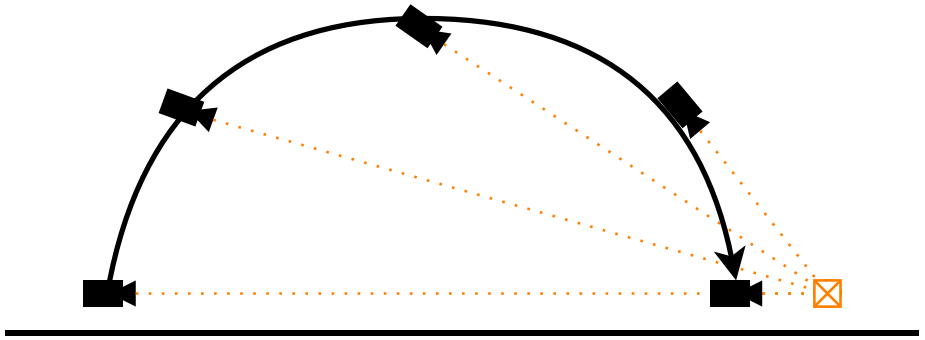


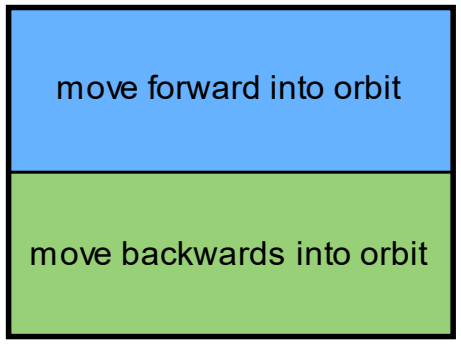
How To Mitigate The Problems? - Automatic Navigation Overhaul

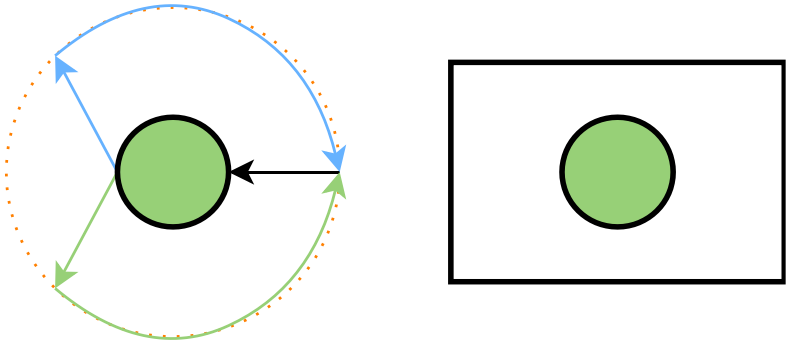
- Old method ignores collisions or target location

- Surface travel also via curves, lifting user to new location (short distances)
- Long distance travel via orbit









Next Steps: How To Measure the Effectiveness?

- Within subjects user study to measure effectiveness of cybersickness mitigations
  - Measure general severity of cybersickness while using CosmoScout VR
- Navigation tasks with and without developed mitigation methods
  - Interplanetary 6-DoF-Navigation with and without grid
  - Automatic navigation using old and new movement, potentially also testing teleportation
- Measuring cybersickness severity and feedback to the navigation methods
  - Continuous evaluation of cybersickness over time inside simulation
  - Feedback and evaluation of features during and after navigation tasks
  - Feedback and SSQ after session