



Jet Propulsion Laboratory
California Institute of Technology

Demonstration of CGI Star Acquisition during CGI TVAC

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Nanaz Fathpour, Zahidul Rahman,
Adolfo Valverde, Milan Mandic,
Acknowledging Jason Hauss and other
FTB Folks

Jet Propulsion Laboratory
California Institute of Technology

Pasadena, CA 91109

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Outline

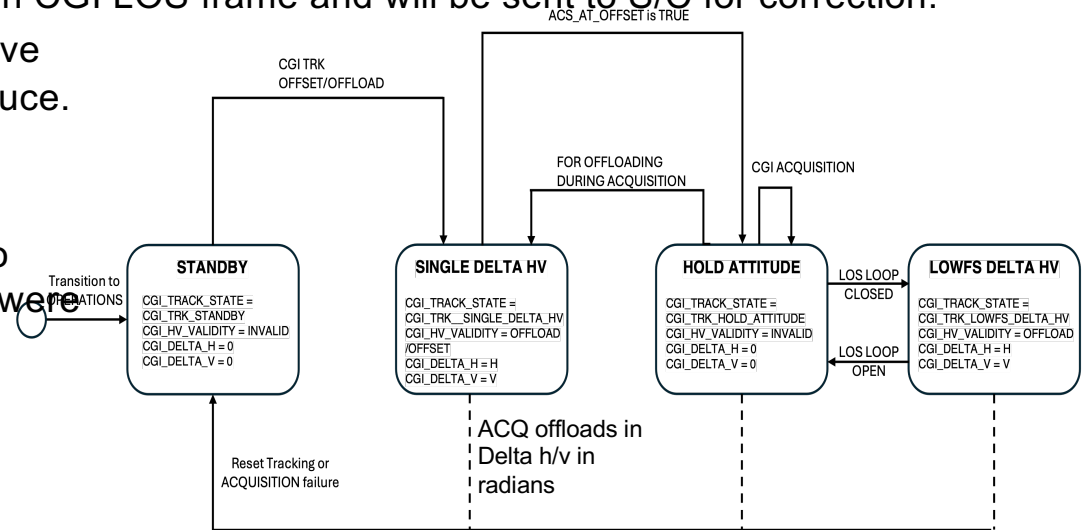
- CGI Star Acquisition Modes
 - EXCAM ACQ
 - Raster Scan ACQ
- CGI – RST ACS FSW communication during star acquisition
- Star Acquisition TVAC Test Results

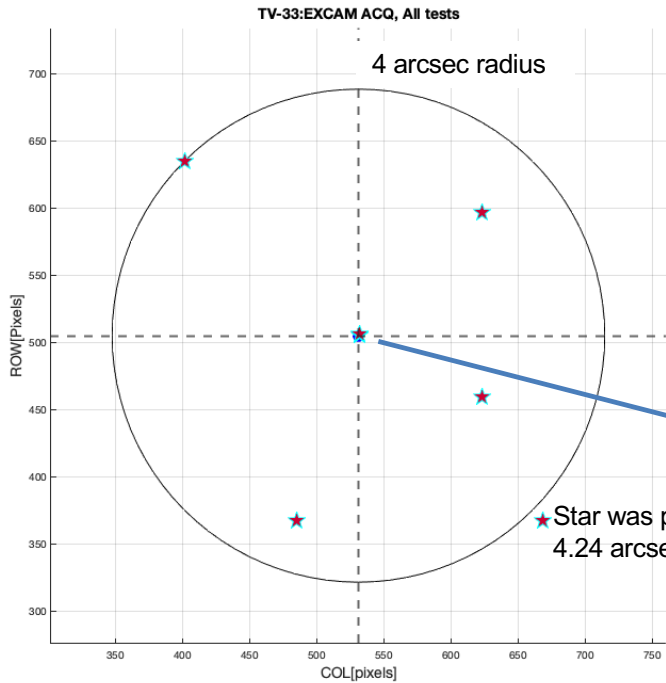
EXCAM ACQUISITION

- CGI EXCAM Star Acquisition happens once per observation.
- It happens when the optical path is unobscured and No Dark Hole yet. (no FPM in the optical path)
- RST ACS brings the star to within 4 arcseconds radius from EXCAM target pixel (CGIRD-602).
- Now that the star is on CGI camera's FOV, ACQ algorithms in *iFSW* finds the star and its location.
- For successful EXCAM Star Acquisition, star needs to be placed within EXCAM capture range (0.0545 arcsec radius from EXCAM target pixel).
 - CGI does not have the pointing capability to bring the star from 4 arcsec to desired threshold (0.0545 arcsec) region.
- CGI computes centroid relative to desired pixel location and sends “offload” to ACS for correction.
- RST ACS provides additional pointing capability to place the star within required thresholds through offloads from CGI to ACS.
 - ACS makes the correction, until the star is within desired threshold of 0.0545 arcsec.
 - This is to inset the FPM and align the star on the FPM to take initial image and complete initial acquisition process, including closing the LOS loop and start offloading FSM strain gauge measurements to ACS.

CGI offloading and outgoing packet to ACS

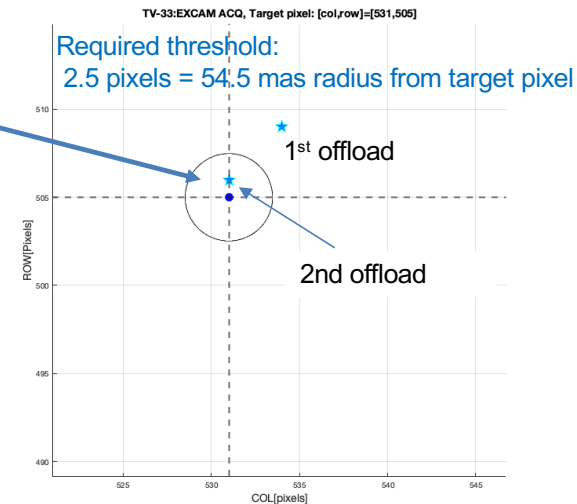
- Throughout CGI star acquisition, RST ACS provides additional pointing capabilities to the CGI through *iFSW*.
- A state machine is used to facilitate exchange of information between two systems.
- The outgoing packet from CGI is called CGI-ACS-TRACKING packet.
 - CGI_TRACK_STATE is the most important field in this packet.
- CGI star Acquisition happens when CGI_TRACK_STATE is in HOLD ATTITUDE.
 - S/C ACS is stable enough.
- Offloads, delta (H,V) are in radians and defined in CGI LOS frame and will be sent to S/C for correction.
- Offloads are treated as ACS attitude errors relative to current attitude that spacecraft will help to reduce.
- RST ACS sends ACS state through flags in CGI_SC_ACS_STATUS incoming packet.
- During CGI tests, state machine for transitions to different tracking states, offloads and ACS flags were tested.





EXCAM ACQ Test Objective:

- To place PSF at different locations in EXCAM FOV (4arcseconds radius), using CVS.
- To be able to find the star and its location.
- To be able to compute centroid and offset from desired pixel location and offload it to ACS (CVS in this case) for correction.
- To place the PSF within required thresholds through offloads.



- During EXCAM star acquisition, using the CVS, PSF (bright and dim) was placed at various locations within EXCAM FoV and successful EXCAM acquisition was demonstrated.

EXCAM ACQ example 1

PSF was placed @ 4.24 arcsec from EXCAM target pixel

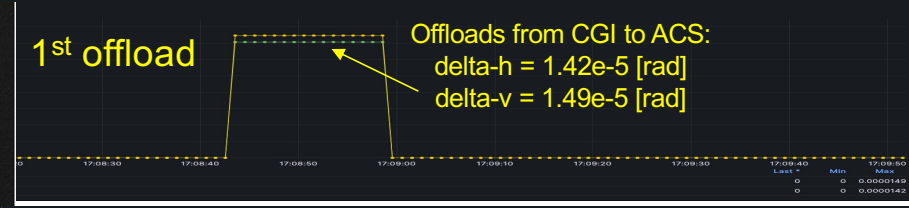
- Bright star EXCAM setup: exposure time = 5s with ND475, gain =1, # of frames = 5.
- CVS places the star at 4.24 arcsec radius from EXCAM Target pixel.
- EXCAM raw frames was cleaned from noise.
- CGI StarID algorithm in iFSW finds the star and its location.
- CGI FindStar algorithm in iFSW computes centroid relative to desired pixel location and sends offload as delta h/v to ACS (CVS in this case) for correction. Tracking state: "SINGLE DELTA HV".
- ACS (CVS in this case) brings the star close to desired pixel location. Tracking state switches to "HOLD ATTITUDE".
- The above repeats until star is within the threshold limit.

EXCAM Acquisition PACE Information

Parameter	Value	Unit
cgj_acq_pace_ex_findstar_col	665	pixels
cgj_acq_pace_ex_findstar_row	364	
cgj_acq_pace_ex_findstar_col_err	134	Error
cgj_acq_pace_ex_findstar_row_err	-141	

PSF .fits
PSF at 4.24 arcsec (194.5 pixels) from EXCAM target pixel.

PSF centroid @[665,364] pixel



EXCAM Acquisition PACE Information

cgj_acq_pace_ex_findstar_col	534	
cgj_acq_pace_ex_findstar_row	509	
cgj_acq_pace_ex_findstar_col_err	3.18	Error is reduced to
cgj_acq_pace_ex_findstar_row_err	3.60	

After 1st offload, PSF at 0.147 arcsec (4.2 pixels) from EXCAM target pixel

PSF centroid @[534,509] pixel



EXCAM Acquisition PACE Information

cgj_acq_pace_ex_findstar_col	531	
cgj_acq_pace_ex_findstar_row	506	
cgj_acq_pace_ex_findstar_col_err	-0.121	Within pixel threshold
cgj_acq_pace_ex_findstar_row_err	0.111	

After 2nd offload, PSF at 0.027 arcsec (0.1 pixel) from EXCAM target pixel

PSF centroid @[531,506] pixel

Requirement Verification Status

DNG ID	Title	Status	Notes	Expected VCR completion Date
905464	REQ: L4 FSW - ACQ - EXCAM Acquisition - CGI_ACQ_ACQUIRE_EXCAM()	Pass	Demonstrated successfully for stars with Vmag =0, 3 and 5 with added disturbances.	N/A
758642	REQ: L4 FSW - ACQ - EXCAM Acquisition - EXCAM ACQ STAR ID completion time	Pass	Finished in 17s, Req: 60s	N/A
758640	REQ: L4 FSW - ACQ - EXCAM Acquisition - EXCAM ACQ FIND STAR completion time	Pass	Finished in < 1s, Req: 20s	N/A
838206	REQ: L4 FSW - ACQ - EXCAM Acquisition - EXCAM Offloads	Pass	Offloads generated and done through CVS	N/A
1072262	REQ: L4 FSW - ACQ - EXCAM Acquisition - EXCAM ACQ FIND STAR centroid accuracy	Pass	Error < 0.45 pixels	N/A
1072261	REQ: L4 FSW - ACQ - EXCAM Acquisition - CGI_ACQ_ACQUIRE_EXCAM performance	Pass	Demonstrated successfully after offloading.	N/A
673818	REQ: L3 CGI - CGI Acquisition Phase - For initial acquisition, CGI shall have star acquisition range no less than 4 arcsec radius (3-sigma) on sky equivalent of center of the CGI Direct Imager.	Pass	This is a L3 requirement, during EXCAM ACQ we showed we can place a star at 4.24 arcsec radius from EXCAM target pixel and do a successful EXCAM Acquisition	3/28/2024

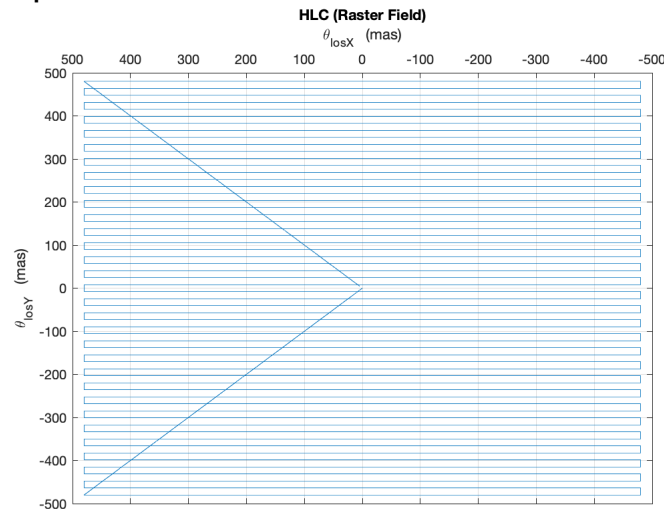
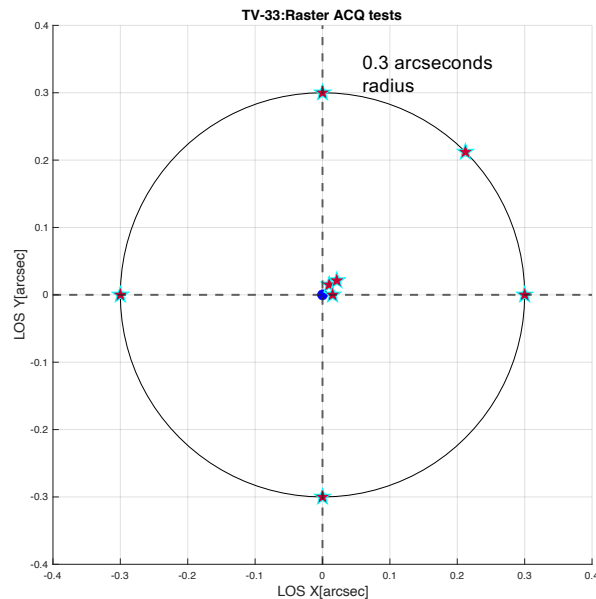
EXCAM acquisition was demonstrated successfully for bright and dim stars and with disturbances ON. All requirements are met!

RASTER SCAN STAR ACQUISITION

- Raster Scan Star Acquisition starts after Dark Hole digging and when required contrast has been achieved and after each slew and roll, for star re-acquisition.
- This is when FPM is in the optical path and blocks most of EXCAM FOV.
- RST ACS will bring the star within 0.3 arcseconds radius of CGI EXCAM center pixel (CGIRD-621).
- FSM rasters the sky and a photon count will be recorded at 1000 Hz as a function of FSM Strain Gauge voltages.
- The scanning of the FSM corresponds to pre-recorded voltage profile for each of PZTs strain gauges. CGI has specific raster trajectories for each mask:
 - These patterns are designed to scan across a specific mask, and each has different feature sizes.
- Raster scan acquisition algorithms finds the star in the image and identify its location.
- This location would be offloaded to the S/C ACS to bring the star within the LOWFSC linear range to close the LOS loop.
- A successful raster scan acquisition closes the LOS loop.

Raster Scan ACQ Test Objective:

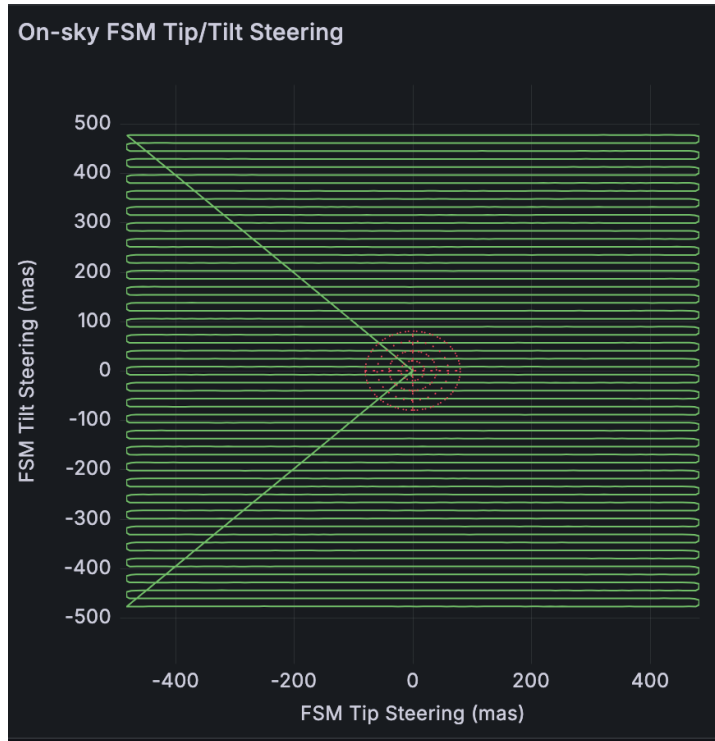
- S/C ACS brings the star within 0.3 arcsec radius during CGI re-acquisition phase
- FSM to raster the sky and FSW to find the star in the image and identify its location.
- To offload the location to the S/C ACS to bring the star within the LOWFSC linear range to close the LOS loop.
- To close the LOS loop and bring FSM to home position.



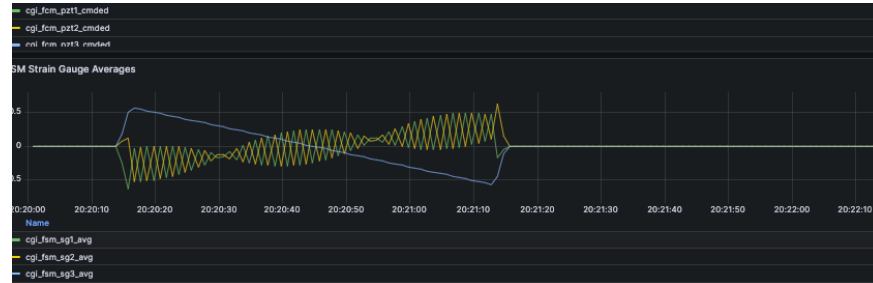
- During Raster Scan star acquisition, using the CVS, PSF (bright and dim) was placed at various locations and successful Raster ACQ acquisition was demonstrated with disturbances on.

Example 1: Raster Scan using the FSM for HLC Mask

FSM rastering the sky for an HLC
mask: 0.48 x 0.48 arcsec



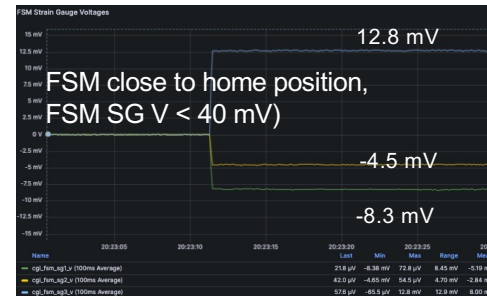
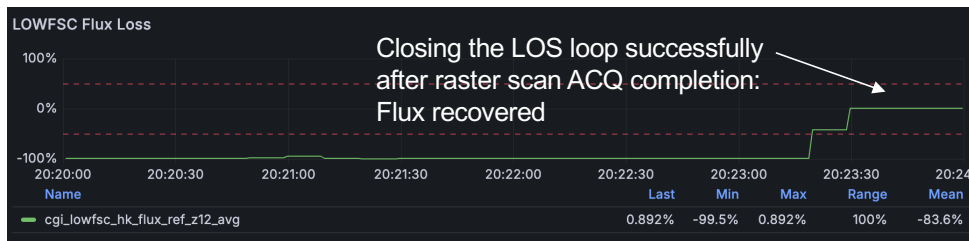
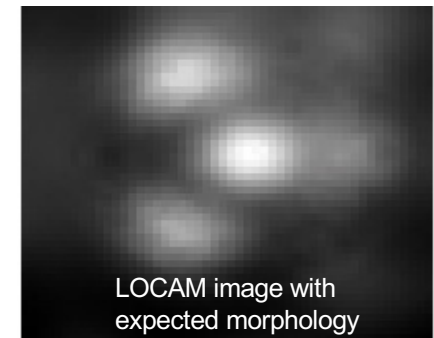
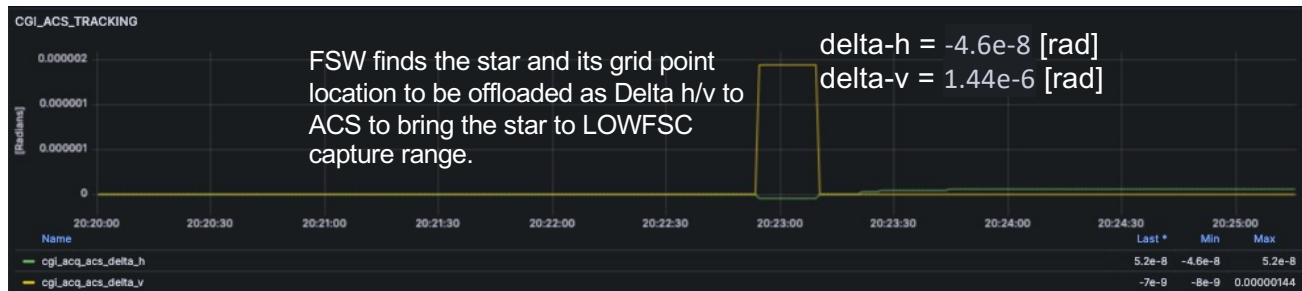
FSM Strain gauge voltages during the raster
scan to create a raster generated image



Algorithm takes in a raster-generated image
and determines whether the star was in the
FOV covered by the FSM raster.

Raster Acquisition bright star @ (-0.3, 0) arcsec

- iFSW takes in a raster-generated image and find the star and its grid point location.
- This grid point location will be offloaded to ACS for correction.



Successful raster acquisition would close the LOS loop and start tracking and FSM SG measurements would be offloaded to S/C ACS as delta h/v.

Requirement Verification Status

DNG ID	Title	Status	Notes
905465	REQ: L4 FSW - ACQ – Raster Scan Acquisition - CGI_ACQ_ACQUIRE_RASTER	Pass	Demonstrated successfully for stars with visual magnitude 0, 3 and 5.
836305	REQ: L4 FSW - ACQ - Raster Scan Acquisition CGI_ACQ_ACQUIRE_RASTER duration	Pass	3 minutes, Req: 5 minutes
838168	REQ: L4 FSW - ACQ - Raster Scan Acquisition - STAR ID algorithm duration	Pass	< 1s, , Req: 20 s
1072263	REQ: L4 FSW - ACQ - Raster Scan Acquisition - FIND STAR accuracy	Pass	Worst case: 18 mas, req: 20 mas
837914	REQ: L4 FSW - ACQ - Raster Scan Acquisition - FIND STAR duration	Pass	< 1s, Req: 20 s
758709	REQ: L4 FSW - ACQ - Raster Scan Acquisition – offload generation	Pass	Offloads generated and done through CVS

Raster acquisition was demonstrated successfully for bright and dim stars and with disturbances ON.

ACS Disturbance Handling

- CGI_SC_ACS_STATUS from RST ACS to CGI sends the ACS status and if it has required pointing stability for CGI observations.
- It contains two flags that indicate if CGI observations must be paused until ACS is at required pointing stability:
 - ACS_RW_ZERO_CROSSING
 - ACS_HGA_MOVE
- If above flags are TRUE, then CGI FSW needs to abort the on-going ground command that uses cameras or closed loops:
 - *iFSW* stores current state on EXCAM, LOCAM and LOS, Focus and Zernike loops.
 - Abort the ground command in progress.
 - Run the logic to set the *iFSW* state to "INACTIVE".
 - Protects the cameras by turning EXCAM off LOCAM to IDLE and opens all loops, if they are already closed.
 - It is expected that ACS would settle to required pointing stability in less than 5 minutes.
 - After receiving the flag that ACS has settled, *iFSW* transitions to "OPERATIONS".
 - Then *iFSW* turns back on all cameras and restores cameras and loops prior states.
- The above was tested for all 17 different ground commands with special handling and for cases that didn't require that.
 - Demonstrated that FSW responds to ACS disturbances and recovers from them successfully!

Requirement Verification Status

DNG ID	Title	Status	Notes
1072268	REQ: L4 FSW - ACS_RW_ZERO_CROSSING or ACS_HGA_MOVE flags when CGI_ACQ_SET_ACS_DIST_RESP_ENABLE and DISABLE	Pass	Demonstrated successfully for various commands in lists A,B and more.

***All ACS disturbance handling cases were successful and met requirements!
Demonstrated that FSW responds to ACS disturbances and recovers from them successfully!
Requirement is met!***

Summary

- All intended objectives for CGI Star Acquisition are met for HLC mask.
 - EXCAM acquisition was demonstrated successfully for bright and dim stars and with disturbances ON.
 - EXCAM Acquisition requirements are met!
 - Raster acquisition was demonstrated successfully for bright and dim stars and with disturbances ON.
 - Raster Acquisition requirements are met!
 - CGI PACE had a bi-weekly meeting with the ACS system from early on and communicated pointing needs during star acquisition and defined our needs before ACS had finalized their design. **Very helpful!**
- All ACS disturbance handling cases were successful, and requirements are met!
 - Demonstrated that FSW responds to ACS disturbances and recovers from them successfully!
- Acquisition algorithms were only tested for HLC mask.
 - Didn't have time/resources to test for other masks.
 - It is important to test acquisition algorithms for different masks before using them during CGI on-orbit observations.
- System level Star Acquisition with ACS in the loop, for offloading, will be tested on orbit for the very first time.
 - If there are any directionality issues, need to update transformation matrices parameters.