Assignment 4 Part 2: MUST3R on Mars

EXTRA CREDIT Grading Rubric - 175 Points

CS498GC Mobile Robotics - Fall 2025

University of Illinois at Urbana-Champaign

Due Date:	December 15, 2025, 11:00 PM CST
Late Due Date:	December 17, 2025, 11:00 PM CST
Instructor:	Prof. Girish Chowdhary (girishc@illinois.edu)
TA:	Kulbir Singh Ahluwalia (ksa5@illinois.edu)

IMPORTANT: Part 2 Moved to Extra Credit

Assignment 4 Part 2 has been moved to **EXTRA CREDIT** per Prof. Girish's direction. Engagement with this challenging work is a strong signal of motivation and resilience—traits aligned with industry and research demands. Top performers will be prioritized for research collaborations.

Official Announcement from Prof. Girish Chowdhary (Dec 7

Assignment 4 Part B – Extra Credit Conversion:
"Assignment 4 Part B is converted to optional extra credit. If you do not submit assignment 4 Part B, it will not impact your final grade calculations. You only need to submit the assignment if you want the extra credit. Otherwise, not submitting this assignment will not impact your final grade calculations."

Grading Policy Clarification:
"If you submit Assignment 4 Part B, you get those points added to your gradable points. If you don't submit it, nothing happens. Grades are calculated with all the assignments, coding exercises, exams, and other graded deliverables as described in the syllabus. Your final letter grade is computed per the syllabus rubric."

Source: Campuswire Announcements, December 7, 2025

TA Message: Why Part 2 Still Matters (Kulbir Singh)

Context: Part 2 was designed for higher rigor and real-world readiness. The required workload is now lighter, but the learning value remains.
Expectations:

- Engaging with the extra-credit Part 2 is a strong signal of motivation and resilience—traits aligned with industry and research demands.
- I will note who leans into challenging work when considering future research roles, startup collaborations, and recommending top students in HALL OF FAME emails to Prof. Girish for LORs.

Opportunities:

- Top performers prioritized for research collaborations: **DASLAB** (http://daslab.illinois.edu/) and **HMR-Lab** (https://hmr-lab.github.io/)
- Compute access, mentoring, potential publications (RSS 2026, IROS 2026, ICRA 2027)
- TA recommendations where appropriate
- DM via Campuswire after Part 2 submission for exciting next steps

Appreciation: Thank you to those who pushed through the difficulty—your effort stands out and **WILL be rewarded accordingly**.

"Let us SLAM on MARS!!"

Assignment Overview

This assignment implements MUST3R (Multi-view Stereo 3D Reconstruction)[1] for **Mars exploration** using a Husky mobile robot. Students choose from **four Mars Gazebo worlds** and demonstrate 3D reconstruction, point cloud processing, and autonomous navigation.

Key Requirements

- Python 3.11 + PyTorch 2.7.0 | CUDA GPU (recommended) or CPU
- ROS2 Jazzy (Ubuntu 24.04) or Humble (Ubuntu 22.04)
- MUST3R: `pip install must3r@git+https://github.com/naver/must3r.git`
- **Mars Gazebo World:** Choose ONE from Section 1

1 Mars Gazebo World Options

v11 Clarification: Use Option 4 (Mars Thanksgiving World)

UPDATE: Use the **Mars Thanksgiving World (Option 4)** for now. Options 1-3 have mesh availability issues reported by students. Thanks to **Gokul Sriramasubramanian** for identifying the missing mesh paths in Option 3 (+1 extra credit).

Option 1: GazeboMarsRover2 (LRCJ)

- **URL:** https://github.com/LRCJ/GazeboMarsRover2
- **Features:** NASA HiRISE terrain, LiDAR/IMU, steering rover
- **Note:** Terrain mesh >100MB (Google Drive download required)
- **Critical:** Add sensor plugins to world SDF (see Section 3)

Option 2: ros2-gazebo-24 (p4mars)

- **URL:** https://github.com/p4mars/ros2-gazebo-24
- **ROS/Gazebo:** ROS 2 Humble, Gazebo Ignition
- **Worlds:** tugbot_depot.sdf, pathfollowing.sdf
- **Setup:** Docker dev container (VSCode recommended)

Option 3: ros2-dual-robot-slam-explorer (itsyashk) – Missing Meshes

- **URL:** https://github.com/itsyashk/ros2-dual-robot-slam-explorer
- **ROS:** ROS 2 Humble or later
- **World:** worlds/mars.world (pre-configured Mars gravity)
- **Features:** Dual robots with laser scanners and cameras
- **WARNING:** Missing mesh paths reported—visual elements may not load correctly. Use Option 4 instead.

Option 4: Mars Thanksgiving World (DASLAB) – RECOMMENDED

- **Source:** DASLAB verified world with working meshes
- **Features:** Camera images confirmed in RViz, Mars gravity configured
- **Status:** Verified (UTM + Ubuntu 22.04 + Humble + Gazebo Fortress)
- **Setup:** Available in course repository (see Campuswire pinned posts)
- **USE THIS:** Meshes are confirmed working. MUST3R + waypoint integration tested.

[1] CVPR 2025

2 Acceptable SLAM Methods

SOTA Methods for Extra Credit

Thanks to **Yuqun Wu** (https://yuqunw.github.io/), partner-in-research, for recommending these state-of-the-art methods.

3D Static Scene Reconstruction (Point Clouds + Meshes + Camera Poses)

- **VGGT** – CVPR 2025 Best Paper Award: https://github.com/facebookresearch/vggt
- **VGGT-SLAM** – Visual Geometry Grounding Transformer for SLAM: https://github.com/facebookresearch/vggt
- **Pi3** – Permutation-Equivariant Visual Geometry: https://github.com/yyfz/Pi3

4D Dynamic Scene Reconstruction (+ Track Dynamic Point Clouds)

- **CUT3R** – Continuous 3D Perception: https://github.com/CUT3R/CUT3R
- **UNI4D** – CVPR 2025, Single Video 4D: https://github.com/Davidyao99/uni4d
- **TTT3R** – Test-Time Training 3D: https://github.com/Inception3D/TTT3R

3 Critical Sensor Plugin Fix

CRITICAL (from Chahit Jain debugging)

Sensor plugins via command line (`-s`) only initialize physics. Add these to your `.world` file:

```
<world name="mars_terrain">
  <plugin filename="libignition-gazebo-physics-system.so"
          name="ignition::gazebo::systems::Physics"/>
  <plugin filename="libignition-gazebo-sensors-system.so"
          name="ignition::gazebo::systems::Sensors">
    <render_engine>ogre2</render_engine>
  </plugin>
  <plugin filename="libignition-gazebo-imu-system.so"
          name="ignition::gazebo::systems::Imu"/>
  <gravity>0 0 -3.71</gravity>  <!-- Mars gravity -->
</world>
```

4 Grading Rubric (175 Points)

Criteria	Points	Excellent (90-100%)	Good (70-89%)	Needs Work (<70%)
1. MUST3R 3D Reconstruction (35 points)				
Model Setup	**12**	Loads MUST3R 512x512 model, GPU/CPU fallback works	Basic config, some optimization missing	Model fails to load
Multi-view Capture	**12**	Synchronized multi-view from Mars world cameras	Basic capture, minor sync issues	Single view or failures
Reconstruction Quality	**11**	Dense, accurate Mars terrain reconstruction	Usable with some noise	Poor quality or fails
2. Point Cloud Processing (25 points)				

PointCloud2 Output	**10**	Proper ROS2 PointCloud2, correct TF frames	Basic output, minor frame issues	Format errors
Filtering/Segmentation	**8**	Voxel filter, outlier removal, ground segmentation	Basic filtering	No filtering
RViz2 Visualization	**7**	Real-time colored point cloud display	Basic visualization	Unable to visualize
3. Mars Navigation (25 points)				
Obstacle Detection	**10**	Accurate detection from Mars terrain point clouds	Basic detection, some errors	Poor detection
Waypoint Navigation	**10**	Follows 10+ waypoints using MoveIt2/Nav2	Basic navigation	Unable to navigate
Path Planning	**5**	Efficient collision-free paths around obstacles	Basic planning	No path planning
4. Screen Recording Demo (40 points)				
Gazebo Simulation	**10**	Mars world visible, robot moving, physics working	Gazebo shown but minor issues	Gazebo not visible
RViz2 Display	**10**	Point clouds, TF tree, robot model all visible	Partial RViz2 shown	RViz2 not shown
MoveIt2/Nav2	**10**	Planning scene, trajectory execution visible	Partial MoveIt2 shown	MoveIt2 not shown
Terminal Windows	**10**	ROS2 nodes, topics, logs clearly visible	Some terminals shown	No terminals visible
5. Rosbag Recording (20 points)				
Sensor Topics	**10**	All sensors recorded: /scan, /imu, /odom, /camera	Most topics recorded	Missing key topics
Point Cloud Topics	**10**	MUST3R output, filtered clouds recorded	Partial recording	No point clouds
6. Documentation (15 points)				
Technical Report	**8**	Clear MUST3R + Mars world integration docs	Good with minor gaps	Poor/missing
Results & Analysis	**7**	Metrics, screenshots, Mars terrain analysis	Basic results	Missing analysis
7. Code Quality (15 points)				
Code Organization	**8**	Clean package structure, proper ROS2 conventions	Functional but messy	Disorganized
Comments & README	**7**	Well-documented, clear setup instructions	Basic comments	No documentation

Bonus	Points	Description
MAST3R Implementation	+10	Use MAST3R instead of/with MUST3R
SOTA Methods (Sec. 2)	+15	Implement VGGT, CUT3R, UNI4D, or TTT3R
Multiple Mars Worlds	+5	Test on 2+ Mars world options
Exceptional Visualization	+5	Novel Mars visualization or navigation
Bug Reports	+1-3	Helpful bug reports (like Gokul's mesh issue)

Table 2: Extra credit opportunities (max +35 bonus points)

5 Extra Credit Bonuses

6 Sample Navigation Waypoints (Mars Thanksgiving World)

Waypoints Navigate Around the Thanksgiving Table

These waypoints are specifically designed for `mars_thanksgiving.world`. The path starts at the green start line, navigates around the Thanksgiving table (at position 3.0, 0.0), visits the rover guest, passes through the boulder zone and crater, reaches the finish line, and returns home.
World file: `/home/kulbir-dgx-x1/assignment4_ws/worlds/mars_thanksgiving.world`

#	Location	X	Y	Yaw	Notes
1	Start Line	-2.0	0.0	0.0	Green marker
2	Approach Table	1.0	0.0	0.0	Head toward table
3	Table Left	3.0	-2.0	1.57	Circle left of table
4	Behind Table	4.5	0.0	0.0	Pass behind table
5	Rover Guest	3.5	1.5	-1.57	Visit martian rover
6	Table Right	3.0	2.0	-1.57	Circle right of table
7	Boulder Zone	5.0	-1.0	0.0	Obstacle avoidance
8	Mars Hill	6.0	1.0	0.52	Terrain navigation
9	Crater Edge	7.0	-0.5	-0.26	Crater observation
10	Finish Line	8.0	0.0	0.0	Red checkered finish
11	Return Path	4.0	1.5	3.14	Head back home
12	Home	-2.0	0.0	3.14	Return to start

Table 3: 12-waypoint Mars Thanksgiving path – navigates around the table (coordinates in meters, yaw in radians)

7 Quick Start Commands

Option 4 (Mars Thanksgiving World – RECOMMENDED):

```
# Clone DASLAB assignment4_ws
cd ~/assignment4_ws/src
# Use mars_thanksgiving world from course repository
colcon build && source install/setup.bash
ros2 launch husky_ur3_gazebo simulation.launch.py world:=mars_thanksgiving
```

Option 1 (GazeboMarsRover2):

```
git clone https://github.com/LRCJ/GazeboMarsRover2.git && cd GazeboMarsRover2
# Download terrain mesh from Google Drive (see README)
colcon build && source install/setup.bash
ros2 launch gazebo_mars_rover2 mars_sim.launch.py
```

Option 2 (p4mars):

```
git clone https://github.com/p4mars/ros2-gazebo-24.git && cd ros2-gazebo-24
```

```
# Open in VSCode -> "Reopen in Container"
colcon build && source install/setup.bash
ros2 launch p4mars_sim sim.launch.py
```

Option 3 (dual-robot-slam – NOT RECOMMENDED):

```
# WARNING: Missing mesh paths - use Option 4 instead
mkdir -p ~/mars_ws/src && cd ~/mars_ws/src
git clone https://github.com/itsyashk/ros2-dual-robot-slam-explorer.git
cd ~/mars_ws && rosdep install --from-paths src -y
colcon build && source install/setup.bash
ros2 launch mars_robots two_robots_sim.launch.py
```

Software Rendering (ARM64/Apple Silicon):

```
export LIBGL_ALWAYS_SOFTWARE=1
export MESA_GL_VERSION_OVERRIDE=3.3
```

8 Research Opportunity

Top 5 Students: DASLAB Research Collaboration

Top performers on this assignment will be considered for research positions:

- **Compute Access:** 2x NVIDIA DGX Spark (256 GB unified GPU memory) + 2x Jetson Thor (128 GB each)
- **Mentorship:** Get mentorship from PhD students working in Physical AI, real outdoor robots. CV: https://kulbir-singh-ahluwalia.com/
- **Publications:** Potential co-authorship on RSS 2026 (Sydney), IROS 2026, ICRA 2027, RAL 2027
- **LORs (conditional on good work):** Potential for collaboration in applied NLP and CV for real mobile robots. Physical AI = Opportunity.
- **Labs:** DASLAB (http://daslab.illinois.edu/) and HMR-Lab (https://hmr-lab.github.io/)

Contact: Kulbir Singh Ahluwalia (ksa5@illinois.edu) with CV/website after submission.

9 Submission Requirements

- **Code:** Python package with MUST3R integration (`must3r_nav/`)
- **Screen Recording (40 pts):** 5-minute video showing ALL of:
  - Gazebo simulation with Mars world and robot
  - RViz2 with point clouds, TF frames, robot model
  - MoveIt2/Nav2 planning and trajectory execution
  - Terminal windows with ROS2 nodes and topic output
- **Rosbag (20 pts):** Recorded sensor data (/scan, /imu, /odom, /camera) + point clouds
- **Report:** 4-page technical report (IEEE format)
- **Mars World Used:** Specify which option (1, 2, 3, or 4) in report

Grading Notes

- Late penalty: -10% per day (max 3 days)
- Bonus: See Extra Credit section (max +35 pts)
- All four Mars world options are valid for full credit (Option 4 recommended)
- **Part 2 is EXTRA CREDIT** – engagement signals motivation for research/TA opportunities

CS498GC Fall 2025 – HALL OF FAME

Quiz 2 Extra Credit Top Performers

- **Michelle Adeline** – 4 Questions, TA-proof quality (exceptional)
- **Chandani Grover** – Extra credit contributions
- **Dominick Braico** – EKF question excellence
- **Sonali Manjunath** – Extra credit contributions
- **Xiayu Zhao** – Extra credit contributions

Assignment 4 Part 1 Early Submission Champions

Gold Tier (+25 bonus):

- **Rishi Kodavati** – Submitted before Nov 7 deadline

Silver Tier (+20 bonus):

- **Mirielle Tan** – Submitted before Nov 9 deadline

Bronze Tier (Early Submissions):

- Chahit Jain, Xiayu Zhao, Praise Daniels, Frank Xu
- Sonali Manjunath, Yingxue Wang, Chandani Grover
- Het Patel, Thea Surya, Aaditya Voruganti
- Nadeem Mohammad, Tongmiao Xu, Yangkun Liu

Technical Contributors

- **Chahit Jain:** Sensor plugin debugging, UTM verification
- **Gokul Sriramasubramanian:** Missing mesh path identification (+1 extra credit)
- **Yuqun Wu:** SOTA method recommendations (VGGT, CUT3R, UNI4D, TTT3R)
- **Mirielle Tan:** Blog on SDF, URDF – Automatic Addison tutorials (https://automaticaddison.com/)
- **Rishi Kodavati:** Assignment 4 Part 2 feedback and debugging

Resources

- MUST3R: https://github.com/naver/must3r
- MAST3R: https://github.com/naver/mast3r
- Course: https://kulbir-singh-ahluwalia.com/cs498gc/fa25/
- Campuswire: #195, #215, #197, #198 + Pinned Posts
- Yuqun Wu (CV Research): https://yuqunw.github.io/

Version 11.0 – December 7, 2025 – 175 Points (EXTRA CREDIT) + Screen Recording Required
v11 Updates: Fixed image placement [H], removed rover note, added Mirielle Tan + Rishi Kodavati credits