**TEKNOFEST**

**AEROSPACE AND TECHNOLOGY FESTIVAL**

**ROBOTAXI-FULL SCALE AUTONOMOUS VEHICLE COMPETITION**

**(UNIQUE VEHICLE CATEGORY)**

**PRELIMINARY DESIGN AND SIMULATION REPORT**

**APPLICATION ID:** 468176

**TEAM NAME:** TUNSA Space Robotics

**VEHICLE NAME:** TUNSA’s Martian Settler Robotaxi (TUNMSR)

**TEAM CAPTAIN:** ELYES KHECHINE

**CONTENTS**

[I. Summary 6](#_Toc99129088)

[A. TUNMSR’s Mission 6](#_Toc99129089)

[B. Vehicle Design Process 6](#_Toc99129090)

[C. Vehicle Unique Aspects 6](#_Toc99129091)

[D. Vehicle Software Architecture 6](#_Toc99129092)

[E. Vehicle Performance 6](#_Toc99129093)

[F. Acquired Skills 6](#_Toc99129094)

[II. Team Organization 6](#_Toc99129095)

[A. Team Introduction 6](#_Toc99129096)

[B. Team Ambitions 6](#_Toc99129097)

[C. Team Members 6](#_Toc99129098)

[D. Task Partitioning 6](#_Toc99129099)

[E. Task Dependencies 6](#_Toc99129100)

[F. Project Preliminary Timeline 6](#_Toc99129101)

[III. Vehicle Features 6](#_Toc99129102)

[A. Vehicle Body & Design 6](#_Toc99129103)

[1. Design Inspiration 6](#_Toc99129104)

[2. Vehicle Dimensions 6](#_Toc99129105)

[3. Vehicle Model 6](#_Toc99129106)

[B. Manual Vehicle Control 6](#_Toc99129107)

[1. Steer-by-wire Design 6](#_Toc99129108)

[2. Pedal-by-wire Design 6](#_Toc99129109)

[3. Brake-by-wire Design 6](#_Toc99129110)

[C. Vehicle Drivetrain 6](#_Toc99129111)

[D. Vehicle Batteries 6](#_Toc99129112)

[E. Automotive User Interfaces 6](#_Toc99129113)

[1. Manual Driving Controls 6](#_Toc99129114)

[2. Autonomous Driving Controls 6](#_Toc99129115)

[3. Infotainment 6](#_Toc99129116)

[F. Vehicle Wiring Harness 6](#_Toc99129117)

[IV. Originality 7](#_Toc99129118)

[V. Sensors 7](#_Toc99129119)

[A. Localization Sensors 7](#_Toc99129120)

[1. Localization Requirements for TUNMSR 7](#_Toc99129121)

[2. Inertial Measurement Unit (IMU) 7](#_Toc99129122)

[3. GNSS Module 7](#_Toc99129123)

[B. Visual Perception Sensors 7](#_Toc99129124)

[1. Perception Requirements for TUNMSR 7](#_Toc99129125)

[2. Computer Vision (CV) Sensor: Options Assessment 7](#_Toc99129126)

[3. Preliminary CV Sensor Choice: Stereo Camera 7](#_Toc99129127)

[4. Time-of-flight Sensors 7](#_Toc99129128)

[C. Powertrain Sensors 7](#_Toc99129129)

[1. Powertrain Requirements for TUNMSR 7](#_Toc99129130)

[2. Electronic Battery Sensor 7](#_Toc99129131)

[3. Temperature Sensor 7](#_Toc99129132)

[4. Transmission Sensor 7](#_Toc99129133)

[5. Wheel-speed Sensor 7](#_Toc99129134)

[D. Breakdown of Sensors 7](#_Toc99129135)

[E. Sensor Wiring 7](#_Toc99129136)

[F. Sensor Mounting 7](#_Toc99129137)

[G. Sensor Autonomy Coverage 7](#_Toc99129138)

[H. Sensor Fusion 7](#_Toc99129139)

[1. Sensor Synchronization 7](#_Toc99129140)

[2. Sensor Raw Data Processing 7](#_Toc99129141)

[3. Sensor Fusion Algorithm 7](#_Toc99129142)

[VI. Vehicle Control Unit 7](#_Toc99129143)

[A. High-level Control Unit 7](#_Toc99129144)

[1. VCU Selection Criteria for TUNMSR 7](#_Toc99129145)

[2. Options Assessment 7](#_Toc99129146)

[3. Preliminary VCU Choice: NVIDIA DRIVE AGX Pegasus Developer Kit 8](#_Toc99129147)

[B. Low-level Control Unit 8](#_Toc99129148)

[1. Longitudinal Actuation 8](#_Toc99129149)

[2. Lateral Actuation 8](#_Toc99129150)

[C. Wireless Control Unit 8](#_Toc99129151)

[1. Wireless Controller 8](#_Toc99129152)

[2. Wireless Communication System 8](#_Toc99129153)

[VII. Autonomous Driving Algorithms 8](#_Toc99129154)

[A. Vehicle Kinematics & Dynamics Modeling 8](#_Toc99129155)

[B. Vehicle 2D Control 8](#_Toc99129156)

[1. Longitudinal PID Control 8](#_Toc99129157)

[2. Lateral Model-Predictive Control (MPC) 8](#_Toc99129158)

[C. Visual Perception 8](#_Toc99129159)

[1. Computer Vision Toolbox 8](#_Toc99129160)

[2. Stereo Camera Data Processing 8](#_Toc99129161)

[3. Semantic Lane Estimation & Tracking 8](#_Toc99129162)

[4. Visual Servoing & Trajectory Drawing 8](#_Toc99129163)

[5. Object Detection 8](#_Toc99129164)

[D. Motion Planning 8](#_Toc99129165)

[1. Global Path Planner 8](#_Toc99129166)

[2. Behavioral Planner 9](#_Toc99129167)

[3. Local Re-Planner 9](#_Toc99129168)

[4. Velocity Planner 9](#_Toc99129169)

[E. State Estimation and Real-time Localization 9](#_Toc99129170)

[1. Options Assessment 9](#_Toc99129171)

[2. Implementation of the UKF 9](#_Toc99129172)

[VIII. Security Precautions 9](#_Toc99129173)

[A. Security Hardware 9](#_Toc99129174)

[1. Signal Lights 9](#_Toc99129175)

[2. Stop Lamps 9](#_Toc99129176)

[B. Battery Management System (BMS) 9](#_Toc99129177)

[1. Voltage Monitoring 9](#_Toc99129178)

[2. Current Monitoring 9](#_Toc99129179)

[3. Temperature Monitoring 9](#_Toc99129180)

[4. State of Charge (SOC) 9](#_Toc99129181)

[5. State of Health (SOH) 9](#_Toc99129182)

[6. Balancing System 9](#_Toc99129183)

[C. Electrical Safety 9](#_Toc99129184)

[1. Ingress Protection (IP) 10](#_Toc99129185)

[2. Low Current Emergency Disconnect Switch 10](#_Toc99129186)

[3. High Current Emergency Disconnect Switch 10](#_Toc99129187)

[4. Emergency Stop Button (Circuit Breaker) 10](#_Toc99129188)

[5. Overcurrent Breakers 10](#_Toc99129189)

[6. Remote Emergency Response System (RERS) 10](#_Toc99129190)

[D. Software Security 10](#_Toc99129191)

[IX. Simulation 10](#_Toc99129192)

[A. Simulation Environment 10](#_Toc99129193)

[B. Map Creation 10](#_Toc99129194)

[C. Implemented Algorithms 10](#_Toc99129195)

[D. Vehicle Mission 10](#_Toc99129196)

[E. Simulation Results 10](#_Toc99129197)

[X. References 10](#_Toc99129198)

# Summary

## TUNMSR’s Mission

## Vehicle Design Process

## Vehicle Unique Aspects

## Vehicle Software Architecture

## Vehicle Performance

## Acquired Skills

# Team Organization

Elyes

## Team Introduction

## Team Ambitions

## Team Members

## Task Partitioning

## Task Dependencies

## Project Preliminary Timeline

# Vehicle Features

## Vehicle Body & Design

Amin

Wael

Mohamed Yassine

### Design Inspiration

### Vehicle Dimensions

### Vehicle Model

## Manual Vehicle Control

Hamza

Hadil

Nesrin

### Steer-by-wire Design

### Pedal-by-wire Design

### Brake-by-wire Design

## Vehicle Drivetrain

Hadil

## Vehicle Batteries

## Automotive User Interfaces

### Manual Driving Controls

### Autonomous Driving Controls

### Infotainment

## Vehicle Wiring Harness

# Originality

# Sensors

## Localization Sensors

Elyes

### Localization Requirements for TUNMSR

### Inertial Measurement Unit (IMU)

### GNSS Module

## Visual Perception Sensors

### Perception Requirements for TUNMSR

### Computer Vision (CV) Sensor: Options Assessment

#### LiDAR

Ameni

Elyes

Afef

#### 3D Flash LiDAR

#### 4D/3D Imaging Radars

#### Pseudo-LiDARs: Stereo Cameras

#### Breakdown Comparison

### Preliminary CV Sensor Choice: Stereo Camera

### Time-of-flight Sensors

## Powertrain Sensors

### Powertrain Requirements for TUNMSR

### Electronic Battery Sensor

Hamza

### Temperature Sensor

### Transmission Sensor

### Wheel-speed Sensor

## Breakdown of Sensors

## Sensor Mounting

## Sensor Autonomy Coverage

## Sensor Wiring

## Sensor Fusion

### Sensor Synchronization

Afef

### Sensor Raw Data Processing

### Sensor Fusion Algorithm

# Vehicle Control Unit

## High-level Control Unit

Oussama

Nesrin

Hadil

### VCU Selection Criteria for TUNMSR

### Options Assessment

### Preliminary VCU Choice: NVIDIA DRIVE AGX Pegasus Developer Kit

## Low-level Control Unit

### Longitudinal Actuation

### Lateral Actuation

Oussama

## Wireless Control Unit

### Wireless Controller

#### Requirements

#### Selection

### Wireless Communication System

#### Wireless Communication Protocols

#### Wireless Control Software

# Autonomous Driving Algorithms

## Vehicle Kinematics & Dynamics Modeling

Fatma

## Vehicle 2D Control

### Longitudinal PID Control

## Lateral Model-Predictive Control (MPC)

## Visual Perception

### Computer Vision Toolbox

#### CNNs

#### TensorFlow

#### Object Detection with YOLOR

### Stereo Camera Data Processing

Oussama

Ameni

### Semantic Lane Estimation & Tracking

### Visual Servoing & Trajectory Drawing

#### Visual Servoing Approach

#### Coordinate Transformations

#### Drawing Planned Trajectory

### Object Detection

#### Traffic Sign Detection

#### Traffic Light Detection

#### Obstacle Avoidance

## Motion Planning

### Global Path Planner

#### Options Assessment

Elyes

##### Hybrid A\*

##### Rapidly-exploring Random Tree (RRT)

##### RRT-A\*

##### ABIT\*

#### Implementation

### Behavioral Planner

#### Options Assessment

##### Finite State Machines (FSMs)

##### Extended Finite State Machines (EFSMs)

##### Hierarchical Finite State Machines (HFSMs): Harel Approach

##### Behavior Trees (BTs)

#### Implementation

### Local Re-Planner

#### Options Assessment

Elyes

##### CBB-RRT\*

##### Lattice-based Path Planner

##### Optimal Control Improvement

#### Implementation

### Velocity Planner

#### Options Assessment

##### Trapezoidal Profile Generation

##### Position Quintic Polynomial for Trajectory Generation

##### Speed Quartic Polynomial Trajectory Generation

##### Symmetric Polynomial Trajectory Generation

#### Implementation

## State Estimation and Real-time Localization

### Options Assessment

#### Extended Kalman Filter (EKF)

Afef

#### Error-State Extended Kalman Filter (ES-EKF)

#### Unscented Kalman Filter (UKF)

### Implementation of the UKF

# Security Precautions

## Security Hardware

Elyes

### Signal Lights

### Stop Lamps

## Battery Management System (BMS)

### Voltage Monitoring

### Current Monitoring

### Temperature Monitoring

Hadil

### State of Charge (SOC)

### State of Health (SOH)

### Balancing System

## Electrical Safety

### Ingress Protection (IP)

### Low Current Emergency Disconnect Switch

Ameni

Elyes

### High Current Emergency Disconnect Switch

### Emergency Stop Button (Circuit Breaker)

### Overcurrent Breakers

### Remote Emergency Response System (RERS)

## Software Security

# Simulation

## Simulation Environment

Fadhel

## Map Creation

## Implemented Algorithms

## Vehicle Mission

Racem

## Simulation Results

# References