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- **Problem Statement ID - SIH25175**
- **Problem Statement Title - MAITRI : An AI Assistant for Psychological & Physical Well-Being of Astronauts**
- **Theme - Space Technology**
- **PS Category- Software**
- **Team ID -57893**
- **Team Name - Zillion Minds**
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मैत्री -MAITRY

An AI Assistant for Psychological & Physical Well-Being of Astronauts

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Understanding The Problem

- **Delayed Detection: Lack of real-time monitoring leads to late identification of critical health and psychological issues.**
- **Limited Context: Generic tools fail to capture astronaut-specific emotional, cognitive, and physical nuances.**
- **Fragmented Insights: Audio, video, and behavioral data remain unconnected, reducing accuracy and decision-making effectiveness.**
- **Ineffective Support: Existing systems lack adaptive, human-like interaction for stress relief and emotional resilience building.**
- **Poor Autonomy: Dependence on ground communication slows interventions in emergencies, risking mission-critical safety lapses.**

Our Unique Solutions

- **Astronaut-Centric Design:** Specifically crafted for **space crew's mental & physical well-being.**
- **Lightweight Offline AI:** Optimized using **ONNX/TensorRT for edge deployment** in **isolated environments.**
- **Contextual Intelligence:** Learns from **prior interactions for personalized, evolving responses.**
- **Critical Escalation Protocols:** Instantly **flags emergencies** with **detailed logs** to ground control.
- **Emotion-Driven Interventions:** Goes beyond detection to deliver **situational, supportive actions.**
- **Resilient Functionality:** Robust against **connectivity loss, noise**, and **equipment interruptions.**
- **Integrated Multimodal Setup:** Simultaneous analysis of **speech tone, facial micro-expressions,** and **textual sentiment.**

USPs

- Real-time emotional mapping for instant crew wellness checks.
- Lightweight AI tuned for deep-space isolation challenges.
- Context-aware micro-interactions to sustain mental resilience.
- Seamless integration with onboard systems for autonomous support.

Our Solution

- **Real-Time Monitoring:** Continuous **multimodal tracking of voice, face,** and **behavioral cues.**
- **Adaptive Conversations: Context-aware dialogue engine** offering **stress relief** and **motivation.**
- **Multimodal Fusion:** Combines **audio, video, and text** for accurate **emotional state recognition.**
- **Autonomous Operation:** Fully **offline system** ensures reliable **functioning without ground dependency.**
- **Actionable Insights:** Generates **daily wellness trends** and critical **incident alerts.**
- **Guided Interventions:** Provides **relaxation techniques**, reminders, and **supportive prompts.**
- **Human-Like Interaction:** Maintains **companionship role** through **short, low-cognitive-load dialogues.**

SCAN FOR PROTOTYPE

https://maitry-ai.vercel.app/

Click here for Prototye:-

75% OF THE PROTOTYPE IS ALREADY COMPLETED!!!

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Technical Approach

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Methodology

- **Multimodal Data Acquisition :Capture astronaut's audio (tone, MFCC, pitch), video (facial landmarks, posture via CNN/Mediapipe), and optional physiological signals (HRV, sleep logs, respiration).**
- **Signal Preprocessing : Apply noise reduction (spectral subtraction for equipment hum), speech-to-text (ASR), and face detection/landmark tracking (MTCNN/Mediapipe).Synchronize audio-video streams for temporal consistency.**
- **Feature Extraction : Audio: Mel-spectrograms, stress & prosody features.Video: Micro-expressions, FACS (Facial Action Coding System), fatigue metrics. Text: Context embeddings via BERT/DistilBERT for intent detection.**
- **Multimodal Fusion & Emotion Classification : Use Transformer-based fusion (cross-attention) or LSTM+CNN hybrid to integrate features. Classify into emotional states (Calm, Anxious, Fatigued, Stressed) with confidence calibration to reduce false alerts.**
- **Decision & Adaptive Response : Decision Layer: Normal → Supportive small talk, Moderate → Guided relaxation cues, Critical → Escalation with logs. Conversational AI (RLHF-tuned) adapts responses over time. Reporting & Logging: Encrypted local DB, daily wellness reports, secure WebSocket uplink for critical alerts.**

Tech Stack

frontend

NEXT.JS · JS · OpenCV · Express JS · tailwindcss

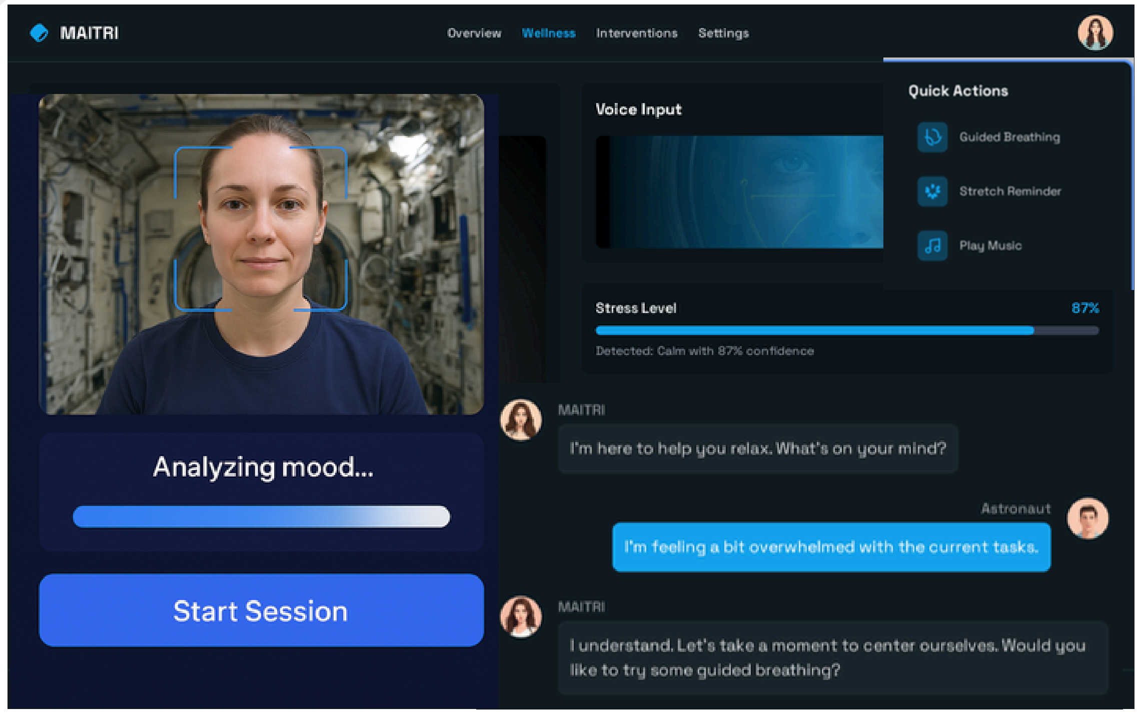
AI Layer & Backend

Hugging Face · deepFace · MediaPipe · Google BERT

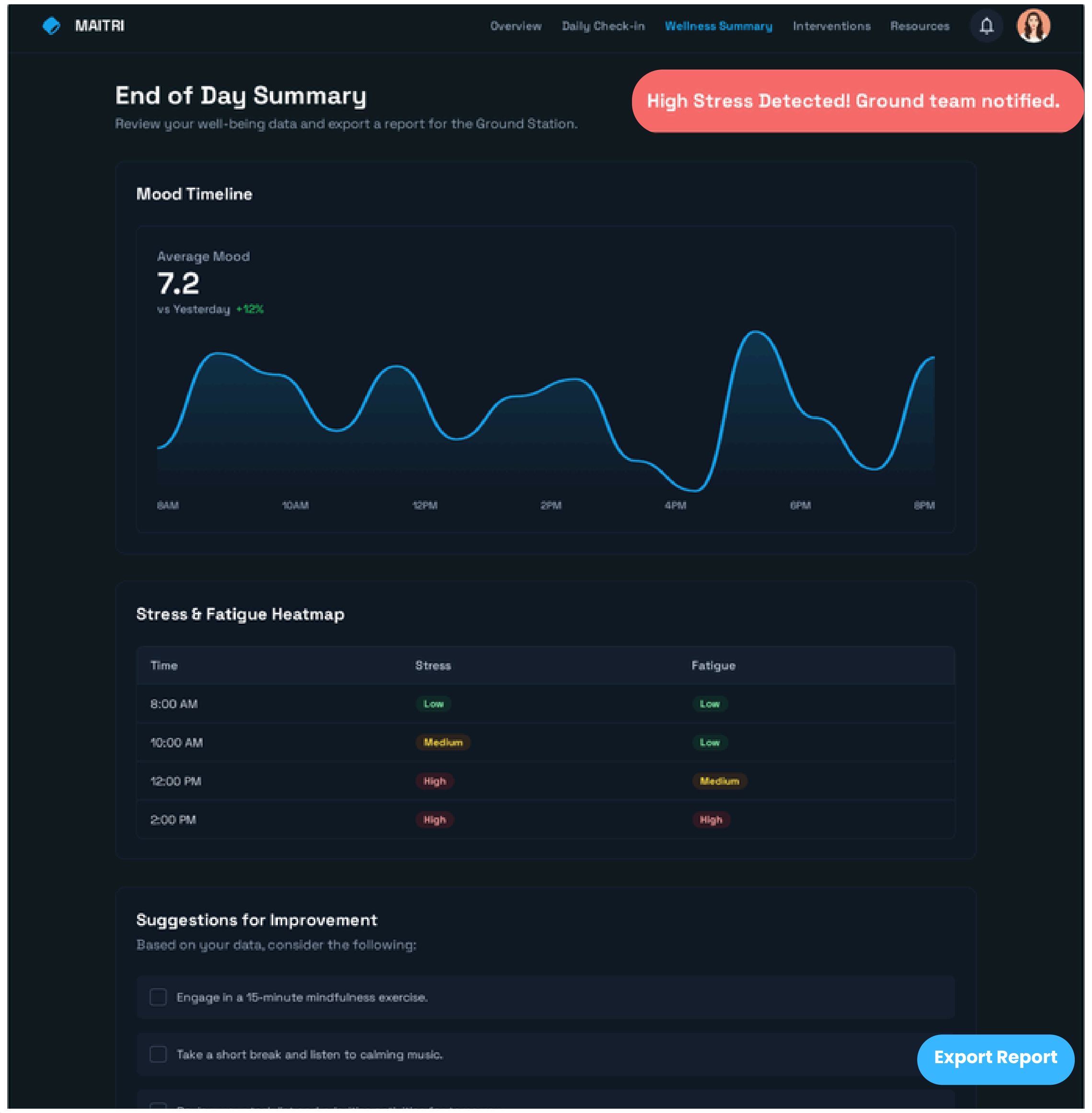
Database & Socket

SQLite

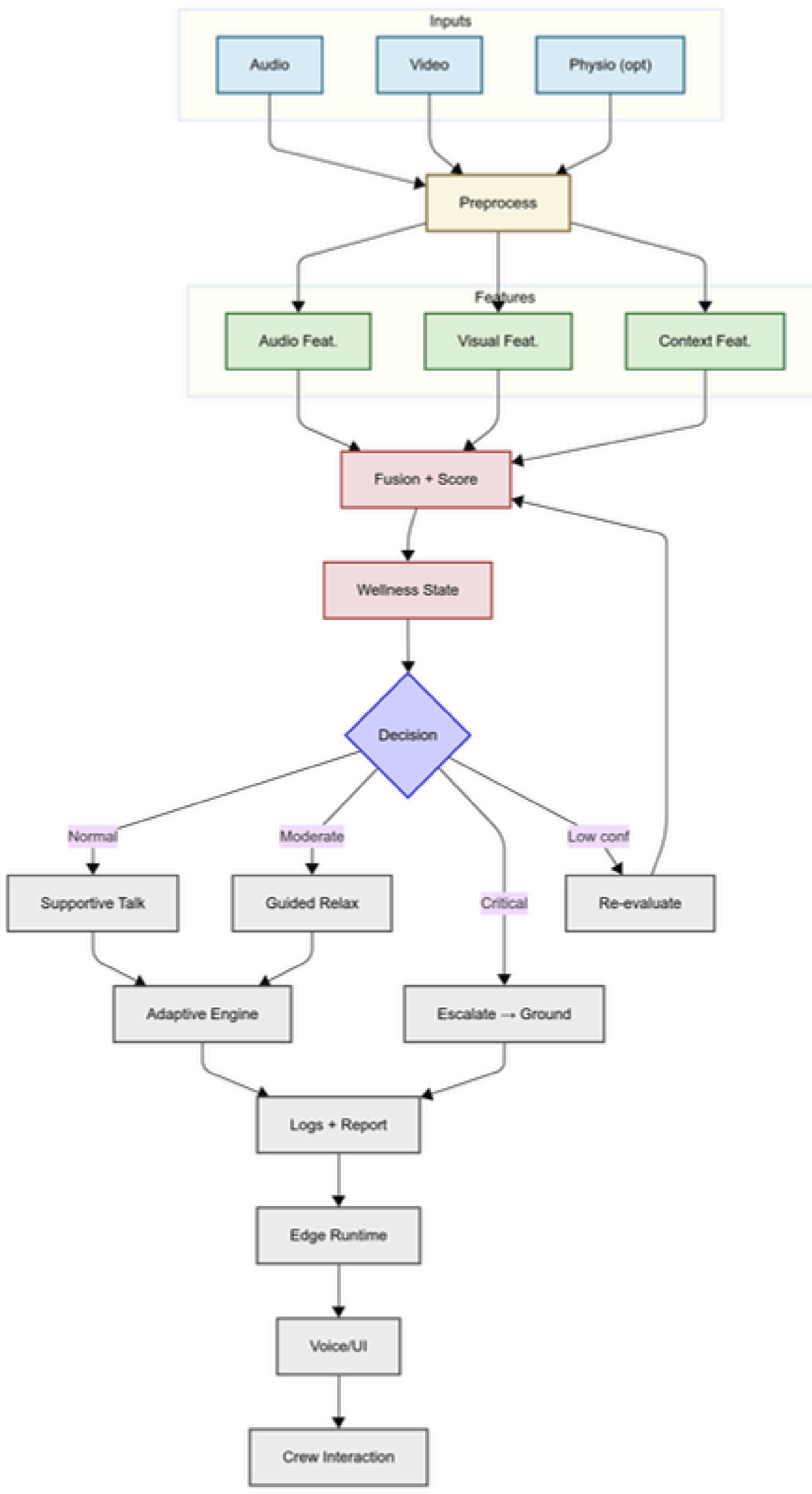
User Interface:



Admin Dashboard



Implementation Flow



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IMPACT AND BENEFITS

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Potential Impact on Astronauts

- **Early Stress Detection –** Identifies **signs of fatigue**, **anxiety**, or **mood shifts before they escalate**.
- **Emotional Stability –** Guided **relaxation** and **micro-interactions** sustain psychological balance.
- **Companion Role – Human-like conversations** reduce isolation during long missions.
- **Task Readiness –** Maintains **focus and alertness** for **mission-critical operations.**
- **Adaptive Support – Personalized responses** evolve with each astronaut's needs.

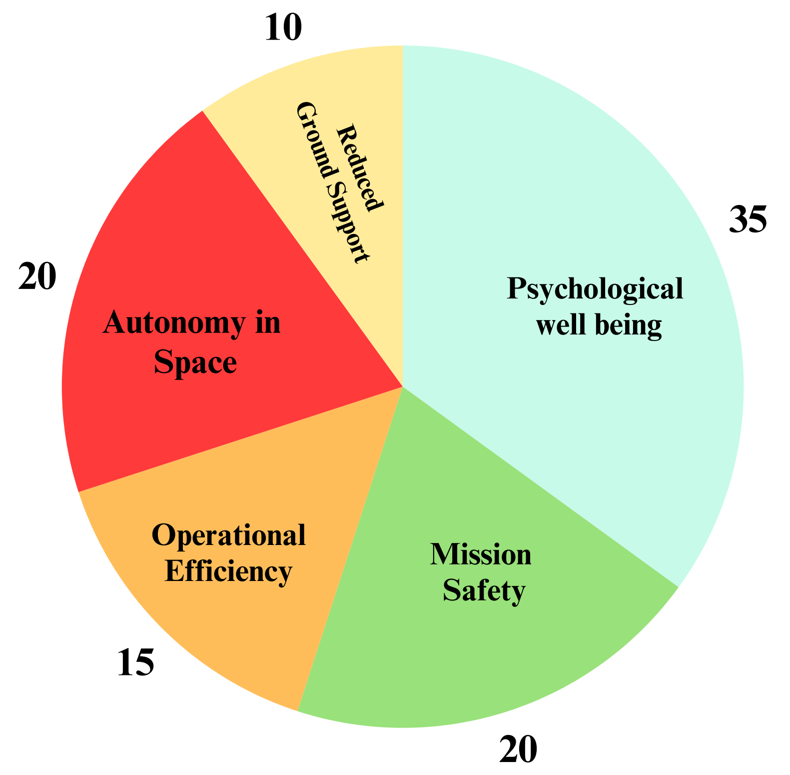
Mission & Opeational Benifit

- **Risk Reduction – Continuous monitoring** lowers chances of human error in space.
- **Autonomous Safety – Works offline**, ensuring **reliability** during communication blackouts.
- **Efficient Crew Management – Optimizes** assignments **based on wellness insights.**
- **Extended Mission Feasibility –** Enables safe **long-duration missions** up to 18 months.
- **Crisis Handling –** Escalates **emergencies instantly with detailed logs** to ground control.

Economic and Strategic Gains

- **Mission Cost Savings – Prevents medical emergencies** during missions, **saving** an estimated **$50–100M per mission**.
- **Resource Optimization –** Lightweight AI **reduces spacecraft energy use** and eases hardware load.
- **Scalable Growth –** Can expand from **simple emotion detection to advanced astronaut healthcare.**
- **Global Leadership –** Establishes a strong position in **astronaut-focused AI innovation worldwide.**

Proportional impact of MAITRI across key domains.



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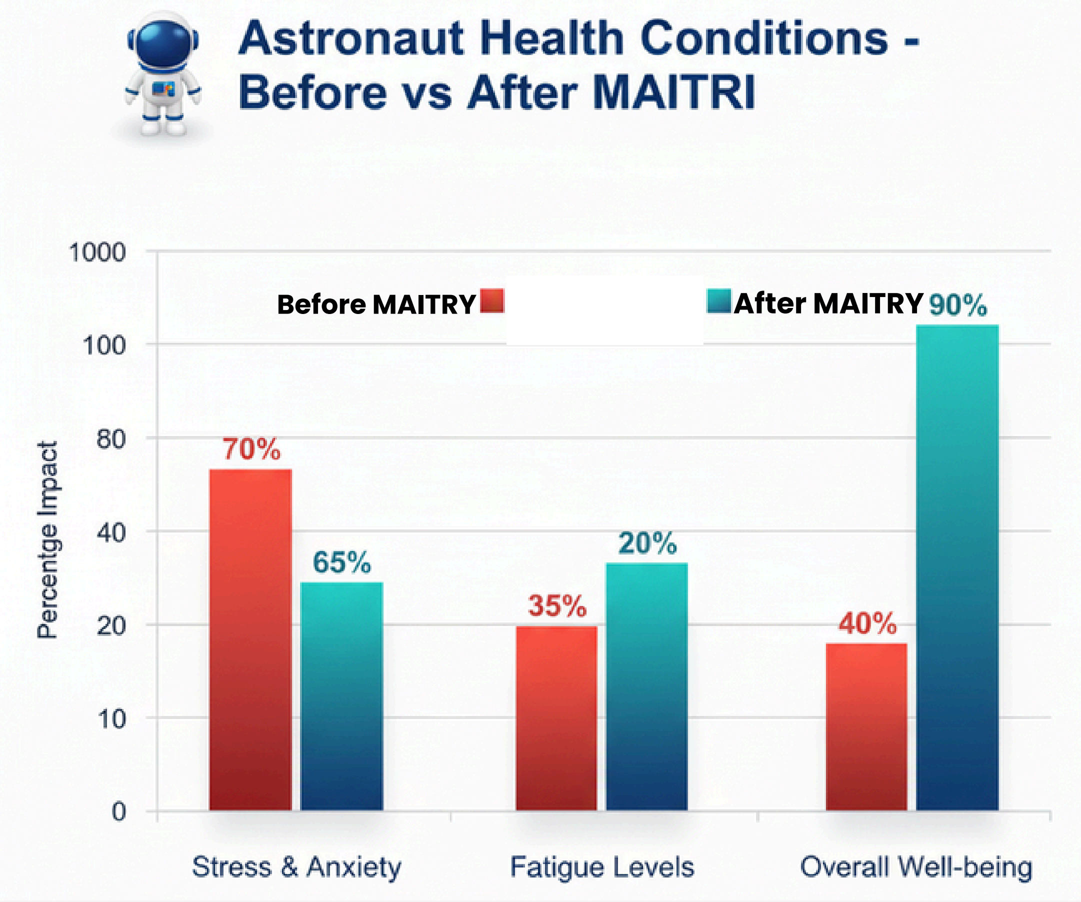
FEASIBILITY AND VIABILITY

Analysis of the feasibility of the idea:

- **Proven Research Base:** Emotion recognition via audio-video **validated in healthcare & HCI studies.**
- **Hardware Compatibility:** Edge devices (**Jetson, ARM**) can run **optimized AI models.**
- **Scalability:** Expandable from **emotion detection to advanced mental health support.**
- **Training Data Availability**: **Open datasets** for speech, facial emotion, and sentiment.
- **Operational Reliability:** Offline system **works during communication blackouts.**
- **Energy Efficiency**: Optimized models ensure **low power consumption** in space modules.



WHAT IFs....?

01 — AI misinterprets emotions?
A fallback rule-based system ensures neutral, safe responses without escalating stress.

02 — hardware fails mid-mission?
Redundant backup modules and lightweight software replicas maintain continuity.

03 — astronauts reject AI support?
Humanized, companion-like interaction design encourages trust and voluntary usage.

04 — extreme conditions distort inputs?
Noise reduction and adaptive models fine-tuned for space environments minimize errors.

05 — prolonged use creates dependency?
Built-in balance ensures the AI assists without replacing human decision-making or autonomy.

Strategies to Overcome Challenges

Limited Onboard Computing Power

- Challenge: Heavy AI models may not run efficiently in space hardware.
- Strategy: Use optimized, lightweight AI models **(DistilBERT, MobileNet, TinyML)**, model pruning, and quantization for offline deployment.

Accuracy with Limited Data

- Challenge: Lack of large astronaut-specific datasets may reduce detection accuracy.
- Strategy: Apply transfer learning from large **Earth-based datasets**, simulate space conditions for synthetic data, and use incremental learning to adapt over time.

Maintaining Trust & Engagement

- Challenge: Astronauts may find responses repetitive or misclassified alerts annoying.
- Strategy: Implement multi-modal detection **(voice + facial + physiological signals)** with adaptive, personalized conversations and confidence scoring to minimize false alerts.

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RESEARCH & REFERENCES

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Feature	Our Proposed Solution	Existing Conventional Solutions
Methodology	**Multimodal Fusion:**Combines audio (voice tone) and visual (facial expressions) data for a comprehensive understanding.	**Single-Modality:** Primarily uses voice command processing or text-based diagnostics.
Model Assumptions	**Direct Correlation:** Assumes that non-verbal cues and subtle data patterns are crucial for well-being monitoring.	**Explicit Intent:** Assumes user intent is clearly expressed through voice or symptom reporting.
Handling of Periodicity	**Proactive:** Monitors for long-term trends and periodic changes in an astronaut's emotional state.	**Reactive**: Only responds to explicit commands or reported issues, with no long-term analysis.
Adaptability	**High Adaptability:** Tailors its conversational style and interventions to the individual astronaut's personality and mood.	**Limited Adaptability:** Follows pre-programmed scripts or rigid conversational flows.
Computational Cost	**Higher:** Requires more processing power for real-time multimodal data fusion. Optimized for on-device operation to mitigate this.	**Lower:** Designed for simpler tasks or relies on vast cloud-based computational resources.
Performance (Metrics)	**Subjective:** Evaluated on the accuracy of emotion detection and the effectiveness of interventions, measured through user satisfaction and well-being metrics.	**Objective:** Measured by task success rate (e.g., retrieving a document) or diagnostic accuracy.
Data Requirements	**Extensive Multimodal Data:** Needs large, diverse datasets of audio and video with corresponding emotional labels.	**Task-Specific Data:** Requires datasets of medical knowledge or operational procedures.

Research and Datasets references

- **IEMOCAP — multimodal dataset (speech + text + video) widely used for training MER models.**

https://sail.usc.edu/iemocap/

- **WESAD — dataset for wearable stress and affect detection using physiological signals (HRV, respiration).**

https://archive.ics.uci.edu/ml/datasets/WESAD+(_Wearable+Stress+and+Affect+Detection)

- **Synthetic Astronaut Training Data — NASA/ESA initiatives on simulating astronaut stress & fatigue signals**

https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Astronauts/Space_psychology

- **RAVDESS — audio-visual emotion dataset including speech and facial expression recordings.**

https://zenodo.org/record/1188976

- **Model training things:Transformer-Based Fusion for Multimodal Signals**

https://arxiv.org/abs/2012.11871

- **ONNX & TensorRT Optimizations for Edge AI**

https://docs.nvidia.com/deeplearning/tensorrt/developer-guide/index.html

- **TinyML for Space Applications**

https://www.nature.com/articles/s42256-021-00399-7