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Solution Plan: Mission Whisper - AI-Powered Astronaut Stress Monitoring System

Overview

This solution plan outlines the design of **Mission Whisper**, an AI system for monitoring astronaut stress during space missions. The system integrates voice, facial, biometric, and text data to detect stress and alerts medical staff via a real-time dashboard.

System Components

1. Data Sources

- **Voice Audio Logs**: Captures tone, pitch, and speech rate from astronaut communications.
- **Facial Video**: Records micro-expressions via helmet or cabin cameras.
- **Biometric Sensors**: Measures heart rate, heart rate variability, skin temperature, and sleep patterns via wearable devices.
- **Mission Logs/Journals**: Analyzes text entries for sentiment and emotional cues.

2. Data Preprocessing

- **Audio**: Noise reduction, feature extraction (e.g., MFCCs) using Librosa.
- **Video**: Face detection and alignment using OpenCV; extraction of facial landmarks.
- **Biometrics**: Normalization of physiological signals; handling missing data.
- **Text**: Tokenization, stop-word removal, and embedding generation using BERT.

3. AI Methods

- **Voice Emotion Recognition**: Convolutional Neural Networks (CNNs) or transformers trained on labeled audio datasets (e.g., RAVDESS).
- **Facial Expression Analysis**: Deep learning models (e.g., ResNet) to classify micro-expressions.
- **Biometric Stress Classification**: Random Forest or XGBoost models to predict stress from physiological patterns.

- **Text Sentiment Analysis**: Fine-tuned BERT model to detect emotional valence in logs.

4. System Architecture

Sensors -> Data Preprocessing -> AI Pipelines (Audio/Video/Biometric/Text) -> Risk Score Aggregation -> Dashboard/Alert

- **Sensors**: Wearable devices and onboard cameras collect raw data.
- **Preprocessing**: Cleans and formats data for AI models.
- **AI Pipelines**: Parallel processing of each data type with specialized models.
- **Risk Score**: Weighted combination of model outputs to produce a composite stress score (0–100).
- **Dashboard**: Streamlit-based interface displaying real-time scores and alerts.

5. Tools & Technologies

- **Programming**: Python for development and scripting.
- **AI Frameworks**: PyTorch, HuggingFace Transformers for model training.
- **Audio Processing**: Librosa for feature extraction.
- **Video Processing**: OpenCV for facial analysis.
- **Visualization**: Streamlit for dashboard development.
- **Hardware**: Compatible with wearable sensors (e.g., Fitbit-like devices) and onboard systems.

6. Deployment Considerations

- **Real-Time Processing**: Optimized models for low-latency inference on edge devices.
- **Bandwidth Constraints**: Compressed data transmission to mission control.
- **Privacy**: Encrypted data storage and processing to protect astronaut privacy.
- **Robustness**: Error handling for missing or noisy data in space environments.

Implementation Notes

- Models will be trained on Earth using public datasets (e.g., RAVDESS for audio, CK+ for facial expressions) and synthetic stress scenarios.

- The system will be designed for modularity, allowing updates to individual pipelines (e.g., new biometric sensors).
- The dashboard will prioritize usability, with clear visualizations and customizable alert thresholds.

Next Steps

- Finalize data preprocessing pipelines.
- Select and fine-tune AI models for each data type.
- Design dashboard mockups and validate with target users.