TERAHERTZ-RAYS: NEW TECHNIQUE TO MODEL BONE DEGRADATION AND TO DEVELOP AND PREDICT COUNTERMEASURE EFFECTIVENESS FOR LONG DURATION SPACE FLIGHT TO MARS?

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INTRODUCTION. Space flight is associated with a loss of calcium from bone and muscloskeletal degradation [1-5]. Terahertz (THz) radiation is electromagnetic radiation in a frequency band from 0.1 to 10 terahertz between the infrared and microwave bands and is the next frontier in imaging science and technology. The laboratory of Zhang et al is currently studying uses for T-rays. T-rays (10^{12} Hz or THz waves) have been used to sense images at a cell level [6]. These images have also been used to monitor the moisture content of leaves, the chemical elements in flames, skin burn severity, skin cancer, and bacteria. Most recently Zhang's laboratory used the terahertz band to develop a T-ray microscope for biomedical applications [6] and a 3 dimensional T-ray imaging system [7].

T-RAY MICROSCOPE The T-ray microscope generates and detects free-space picosecond electromagnetic pulses (T-ray signal) by using nonlinear optics, ultrafast laser pulses and computer analysis. Biological and organic compounds have distinct signatures within the THz region, such as molecular vibrational and rotational levels, and this allows their chemical composition to be examined by the THz system. To develop new biomedical instrumentation, Zhang et al used the core technology of electro-optic generation and detection of coherent T-rays and focused on the requirements set by potential medical applications: high dynamic range, fast data acquisition times, and increased sensitivity to enable the detection of single-molecule thick layers. A microscopic system based on the principles of near-field imaging was constructed with micron spatial resolution, and with high sensitivity for sensing, imaging, and analyzing monolayer biomedical samples.

T-RAY COMPUTED TOMOGRAPHY. T-ray tomography is used for 3-dimensional (3D) imaging applications using computed tomography (T-ray CT). T-ray CT allows the three dimensional structure of the target to be imaged and also provides rich spectroscopic information on the targets far-infrared spectral response which may allow functional imaging. T-ray CT is based on the same principle as X-ray CT. T-rays are focused, transmitted through the target, and detected. The target (or emitter and detector) is then raster scanned and rotated. The hardware is a simple extension standard 2 dimensional THz imaging systems. The filtered backprojection algorithm is used to reconstruct the complex refractive index, *n*, of the material. This is repeated for each horizontal cross-section and each frequency to build a 3D spectroscopic image of the target. This method has recently been applied to bone samples. A turkey femur was soaked in ethanol to remove water moisture and then imaged. The size and basic structure of the bone was accurately recovered with a resolution of approximately 3 mm. The internal bone features were not reconstructed accurately as a result of limited resolution and diffraction effects. Work is ongoing to improve the performance of T-ray CT.

CONCLUSIONS. T-ray methodology may provide a new technique for use to model expected bone degradation for long duration space flight to Mars and to develop appropriate countermeasures and predict their effectiveness. One could also theorize that a new, mobile noninvasive device could be designed to allow real time monitoring of the status of changes in the structure of the bones of astronauts during long term space flight enroute to Mars by comparing changes with baseline data obtained on Earth during ground-based studies and prior to space flight. Much additional experimental work is needed to understand the interactions between THz radiation and biological molecules, tissues [8] and bone.

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