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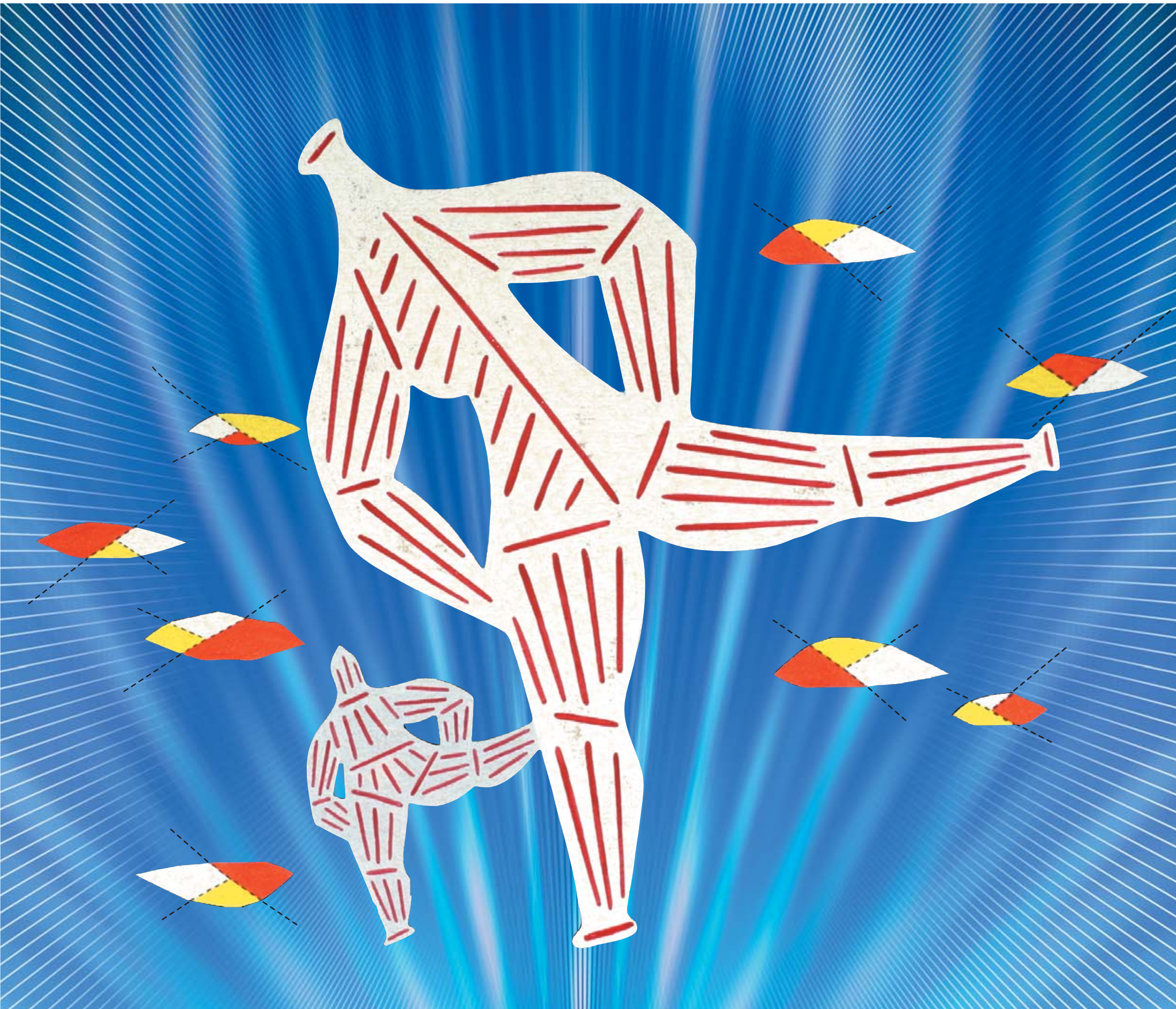
NICT NEWS

National Institute of Information and Communications Technology



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Next-Generation Satellite Laser Communications System

— Inter-Satellite High-Capacity Laser Communications Technology —

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Introduction

Recent years have seen the emergence of a number of international projects for communications, positioning, or Earth-monitoring services using the many Low-Earth Orbit (LEO) satellites (in fact located both in low and medium orbits). Some of these projects have since led to notable practical applications. An example of one such first-generation LEO service may be seen in the US Iridium satellite-telephone system, in which approximately 70 satellites are placed in orbit at an altitude of 700 km for a range of mobile phone services. Commercial services were temporarily discontinued because the company could not compete with ground-based wired and wireless networks in densely populated areas. They are now providing communications services only to particular fields, such as those involving national security and anti-disaster measures, as well as offering services to sparsely populated and oceanic regions. Nevertheless, satellite communications remain unmatched in terms of global reach, expandability, and disaster-resistance. To make the most of these strengths, the Hongo Research Center has been conducting its "Global Multimedia Mobile Satellite System (GMMSS) Project" to develop constituent technologies that will form the basis for future high-capacity satellite communications between ground and space platforms (Figure 1).

Development of constituent technologies

To date we have conducted research into the basic concepts and feasibility of a next-generation satellite mobile system as well as investigation of the constituent technologies. We have also studied satellite visibility factors and quality of service regarding hand-over and delay characteristics. Based on our results, we have made recommendations as to the optimum satellite constellation: a circular orbit at an altitude of 1,200 km; an orbital inclination of 55°; ten orbital planes; and 12 satellites per orbital plane (120 in total).

Following are examples of the main constituent technologies we have developed in this project to date. Some of these technologies have potential in a wide range of applications in addition to their use in satellite mobile systems.

● **Development of satellite-mounted equipment for access to the ground**

High-efficiency amplifiers offer potential for use in satellite-mounted phased array antennas. Eschewing conventional materials, we constructed a new type of power amplifier using a gallium nitride semiconductor. To study the feasibility of mounting the amplifier on a satellite, we then conducted environmental evaluations, such as testing of the amplifier's radiation resistance and dispersion properties.

● **Inter-satellite communications technology**

We developed an optical antenna and a transmission evaluator for an "optical inter-satellite" communications terminal. This compact and lightweight terminal achieves single-wavelength data transmission at 2.5 Gbps (Photo 1). We also carried out partial pro-

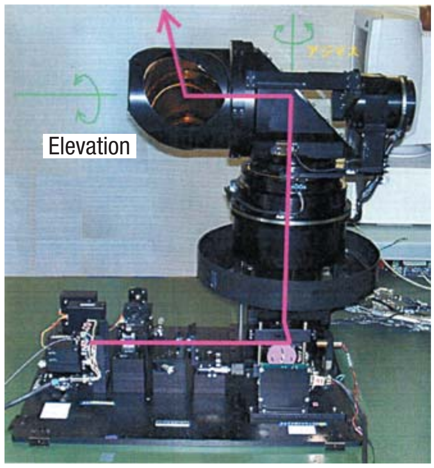
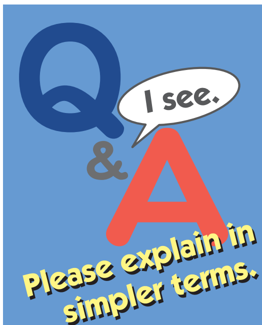


Photo 1:
All-Sky Directive Elbow-Type Optical Antenna System

Designed for communications at 2.5 Gbps (wavelength: 1.5 mm; optical path is indicated as a red line). Use of SiC for lightweight and being unaffected by temperature variation.
High-precision tracking by 2-axis gimbal mechanism: 0.001 deg or less
Wide movement range: ±170° horizontally; elevation angles: -30° to +210° or greater

Ground-based model (bore diameter: 13 cm)
Developed by NEC TOSHIBA Space Systems, Ltd.



Q What is OICETS?

A OICETS stands for Optical Inter-satellite Communications Engineering Test Satellite, a satellite designed to test constituent technologies of inter-satellite communications in orbit using laser beams. These technologies will play important roles in future space missions. JAXA is planning to perform testing in conjunction with the European stationary satellite ARTEMIS, although there is no specific launching schedule at present.

Q What is a gallium nitride semiconductor?

A Gallium nitride (GaN) is a new material used in semiconductor lasers and blue LEDs (light-emitting diodes). Using an existing procedure, GaN is crystallized on a sapphire substrate that is heated to 1,000°C. Depending on the materials used in the substrates or electrodes, GaN semiconductors can be fabricated in different ways. This device has great potential for use in phased array antennas, which require a highly efficient amplifier.

totyping and evaluation of the satellite-mounted system including a control/processing circuit and a finely sensitive acquisition and tracking sensor module/mechanism featuring a receiving collimator fiber assembly.

● **Ground-satellite networking technology**

We developed a ground-satellite network simulator that is compatible with ground-based communications systems; the device simulates multimedia communications via satellite.

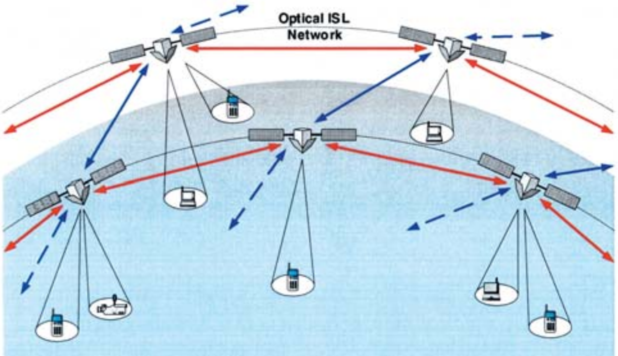


Figure 1: **Next-generation LEO communications**

A constellation of low-Earth orbit (LEO) satellites will be used to provide mobile terminals on the ground with Global Multimedia Mobile Satellite System service, which will allow high-speed transmission of information such as image data. Accordingly, we are planning to conduct verification testing of the necessary optical inter-satellite communications technology.

Inter-satellite communications: High-speed optical inter-satellite communications (up to 2.5 Gbps)

User link connection: Satellite antenna design of 1 user/1 beam

User terminal performance: Multimedia communications up to 2 Mbps

Future of optical inter-satellite communications technology

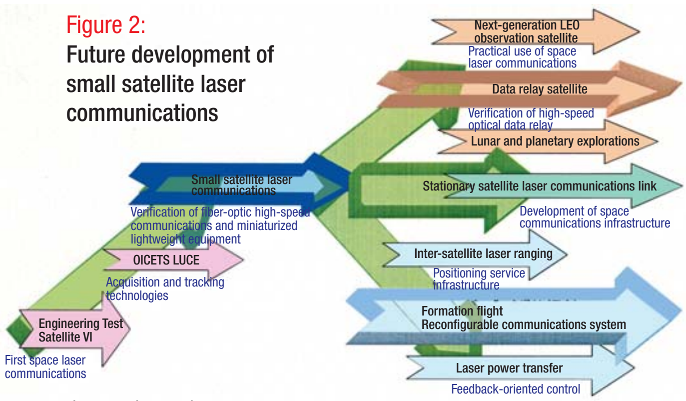
Among the constituent technologies we have developed to date in this project, we are now focusing on optical inter-satellite communications, with the aim of performing verification test of this technology. As shown in Figure 2, the development of the Engineering Test Satellite VI in the 1990s and ongoing OICETS have led to significant contributions to optical inter-satellite communications technology. In this field, the ESA (European Space Agency) has been working on a project for optical data relay between LEO and stationary satellites. In 2001, the agency succeeded in securing communications from SPOT-4 (LEO) to ARTEMIS (stationary) at 50 Mbps. In Japan, JAXA (Japan Aerospace Exploration Agency, formerly referred to as NASDA) has been engaged in the development of OICETS and is planning to perform two-way testing between LEO and stationary satellites. NICT is working to perform verification testing of satellite-mounted laser communications equipment that will be much smaller than the devices used in the above projects (one-third lighter than the equipment in the OICETS mission) but that will nevertheless provide high-speed transmission at 2.5 Gbps.

Through steady progress in miniaturization and increasing capacity, we are now witnessing the prospect of optical inter-satellite technology for common use in a wide range of fields: data relay satellites, deep space exploration, global observation, small-satellite-cluster formation flight, reconfigurable communications systems, and more.

In addition, NICT is engaged in promising joint research with Mitsubishi Heavy Industries. We are planning to launch a small satellite (approx. 150 kg) referred to as “SmartSat” into an elliptical orbit for preliminary verification of optical inter-satellite communications, an in-orbit maintenance system, reconfigurable communications equipment, and space weather observation. To this end, we are conducting a range of activities based on the initial results of this project: verification of optical beacon acquisition and tracking functions with reference to star and planet positions; measurement of optical device properties in the space environment; ground-satellite laser communications testing; and basic and detailed design of equipment to meet the requirements of satellite bus interfaces. Further, as components of the laser communications equipment, we are developing a laser input/output fiber collimator device and a small mirror equipped with beam orientation control for fine acquisition and tracking.

Japan has little experience in operating multiple Earth-orbiting satellites in an organically combined manner or in building global systems in which satellites are linked through laser communications. Therefore, the technologies developed and accumulated in the course of this project will be valuable not only in commercial satellite communications but also in many other fields such as national security, global environmental measurement, resource exploration, space observation, and space data relay.

Figure 2: **Future development of small satellite laser communications**



Increase in speed:
2 Mbps ➔ 50 Mbps ➔ several Gbps ➔ 10 Gbps ➔➔ several hundred Gbps

Conclusion

Anticipating a number of fixed launch schedules, the relevant departments at NICT are cooperating to develop and test engineering models of satellite-mounted equipment that will be able to provide high-capacity transmission despite its globally unparalleled small size.

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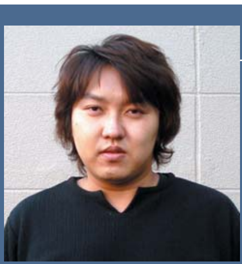
● Development of communications systems expected to lead to synergies with other fields

Compared to existing stationary satellites or LEO satellites (providing communications services now experiencing a notable slowdown in demand), the next-generation LEO satellite system offers superior multimedia communications features. This new system offers high-capacity transmission despite its globally unparalleled small size. Further, technologies discovered in the course of system development will likely find commercial application in many fields other than satellite communications, including areas involving national security, global environmental measurement, and resource exploration. Notably, the development of a next-generation LEO satellite system was selected as part of the Millennium Project.

Free Sharing of Whole-Body Voxel Model Database on Average Japanese Adult Male and Female

— Promotion of High-Precision Numerical Simulations Using High-Resolution Realistic Models in Multiple Fields —



Tomoaki Nagaoka

Expert Researcher,
Biomedical EMC Group
Wireless Communications Department

Graduated from Department of Medical Science, Kitasato University Graduate School in 2004. Joined Biomedical EMC Group as Expert Researcher in October 2004. Currently working on enhancement and sophistication of human-body voxel models. Holds a Ph.D. in medical science.

Introduction

With the recent development of radio wave application technologies, radio waves have seen increasing use in a wide range of areas. With the widespread use of ubiquitous network technology, it is likely that in the future people will carry various types of information terminals on different parts of the body (in addition to today's mobile phones), with each terminal engaged in some form of wireless communication. In this context, radio wave protection guidelines have been established in response to increasing concern about the health effects of radio waves emitted from mobile phones. These guidelines are based on the thermal effects (i.e., stress) caused by the absorption of radio waves into the body, and a specific absorption rate (SAR) is used to indicate the amount of electricity absorbed per unit weight. To ensure adequate protection against radio waves when providing ubiquitous network services, accurate measurement of SAR values for the radio waves emitted from such devices will be essential.

Since it is not possible to perform experimental scanning through an actual human body, it is important to estimate SAR values through numerical simulations using a human-body voxel model. Conventionally, human-head voxel models are used in the calculation of SAR values to assess the effects of mobile phones. However, to assess the effects of ubiquitous network devices that may be used close to different parts of the body, a voxel model of the whole body is required.

To date, several research groups have developed whole-body voxel models. However, these models are based on anatomical data corresponding to Western subjects, with body proportions that differ substantially from those of the Japanese. Another problem is seen in that no female models are available. NICT's Biomedical EMC Group has been carrying out joint research with Kitasato University, Keio University, and Tokyo Metropolitan University to develop the first whole-body voxel models in Japan: TARO (male) and HANAKO (female). These models reflect the body sizes of average Japanese adults (Figure 1). We have begun to offer access to this newly developed voxel model database for free.

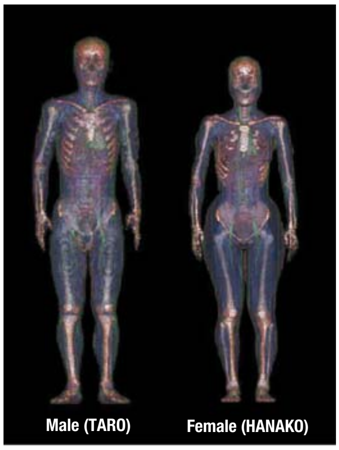


Figure 1: **Three-dimensional display of newly developed models**
Internal tissues are visualized by volume rendering.

Human-body voxel models

In a human-body voxel model, body shapes (tissues, organs) are represented as collections of tiny elements, and these individual tiny blocks are assigned numbers that indicate the name of a tissue type (e.g., muscle, fat) or

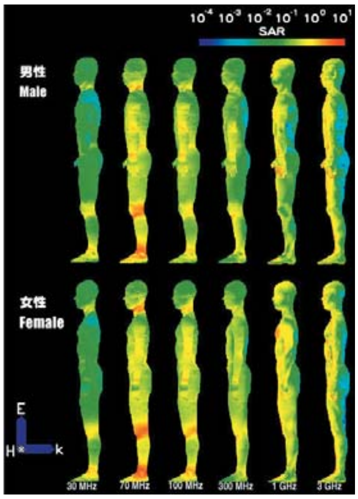
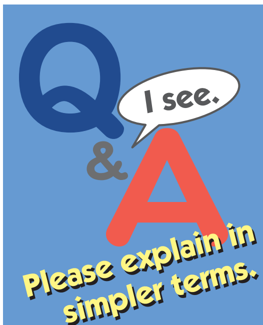


Figure 2:
Color-coding of SAR distribution on the body surface when the front of the body is exposed to vertically polarized plane waves (frequency range: 30 MHz to 3 GHz; radio field intensity: 1 mW/cm²).



Q What are the effects of radio waves on the human body?

A Radio waves cause thermal effects (i.e., stress) on the human body when they are absorbed. Guidelines were therefore established to protect users from the effects of radio waves emitted from mobile phones. A unit of measurement has also been adopted to indicate the amount of radio waves absorbed into the body. The health effects of radio waves have been studied in various countries for more than 50 years.

Q Are there any other whole-body voxel models available to the public?

A Although several whole-body voxel models have already been developed in the West, there is only one model available to the public for free. This model was developed by a US military laboratory (height: 187.1 cm; weight: 105 kg; number of tissues and organs: 43). All consist of male models and their body proportions are substantially different from those of the Japanese.

organ. You can simulate the absorption of radio waves into the body by assigning corresponding electric constants to the tissues and organs (Figure 2). We developed this human-body model database by collecting MRI data from volunteer Japanese adult male and female of average height and weight. These models have 51 tissues and organs with spatial resolution of 2 mm. When we conducted medical editing and analysis of the anatomical data after development, it was revealed out that this database was superior to existing ones in terms of spatial resolution, the number of identified tissues and organs, and accuracy of body part dimensions and organ weights relative to average values for Japanese (Figures 3 and 4).

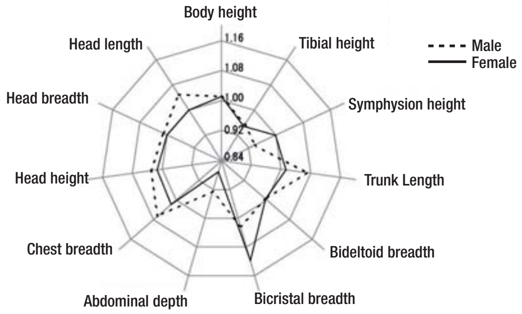


Figure 3:
Comparison of body part dimensions between new models and average Japanese adults
On average, these models deviate by 5% or less from average Japanese adults. (Values in the figure are more accurate as they approach 1.00.)

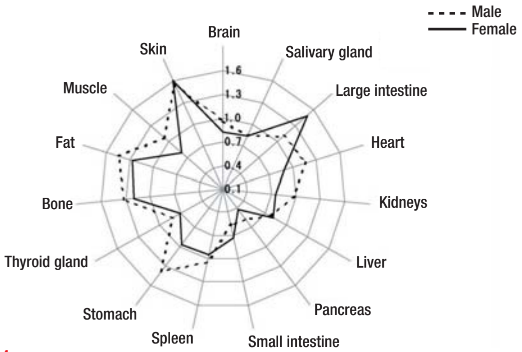


Figure 4:
Comparison of tissue/organ weights between new models and average Japanese adults
60% of the male model's and 80% of female model's tissues/organs deviate by 30% or less from average values. (Values in the figure are more accurate as they approach 1.00.)

Application of this model database is not limited to studies of the mutual effects of radio waves and the human body. By specifying an elastic coefficient or radiation absorption coefficient in a model, analysis of damage to vehicle passengers in collisions becomes possible, in addition to applications such as the preparation of radiotherapy plans for cancer patients.

Free sharing of data

Many researchers at home and abroad sent us requests to share this human-body voxel model database. To respond to these requests and to offer this valuable data for use in various research fields, the body model development group determined conditions for use and established a set of distribution methods. According to our determination, NICT will hold the copyright on the database and manage distribution of the data. For the time being, we will offer free access to users for nonprofit research purposes. On November 1, 2004, we began to accept applications for use of the database at: http://www2.nict.go.jp/mt/b186/bio/bio_human_model.html.

Conclusion

We continue to improve our human-body voxel models, for example with the addition of tissue types and standardization of internal tissue weights. We also plan to upgrade this database periodically. We are now working on the development of a highly sophisticated human-body model that will allow the user to freely change its posture, physique, and resolution (Figure 5). Although the human-body numerical database is currently intended for use in non-profit research activities, we are planning to consider offering fee-based access for commercial use.

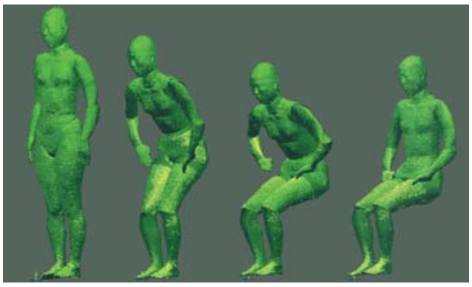


Figure 5: **Example of highly sophisticated human-body model (modifiable-posture model)**
Change from an upright posture to a sitting posture (female model)

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● Potential for wider application

Application of this new model is not limited to studies of the effects of radio waves on health. If you specify an elastic coefficient (which indicates the deformation of a substance caused by an external force) or radiation absorption coefficient for a given model, application becomes possible in many fields, for example in the analysis of damage to the human body in a traffic accident or in the preparation of radiotherapy plans for cancer patients. Further, the development of a highly sophisticated human-body model will enable modification of the body's average physique according to target age (from children to the elderly) or the assessment of the effects on health in actual postures (such as the real-life positions of mobile phone users).

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Observation of Disaster Areas Shortly after the Niigata Chuetsu Earthquake

Airborne Imaging Radar

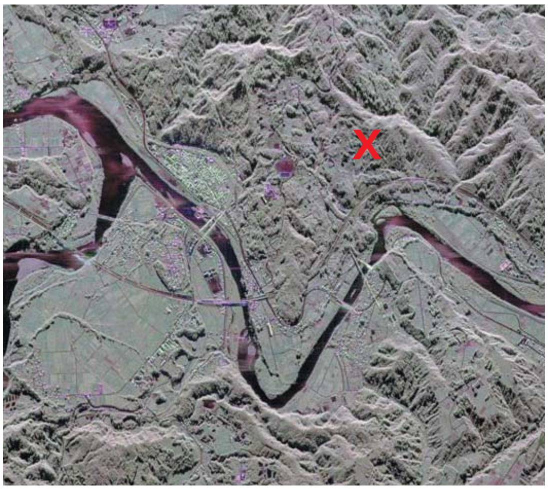

Figure 1: Area (4 km x 4 km) around the epicenter in Uonuma City (formerly Kawaguchi Town), Niigata Prefecture. "X" denotes the epicenter.

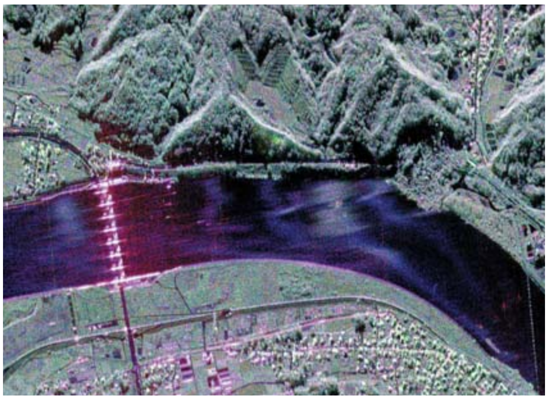

Figure 2: Site of landslides (upper side of curve in the river) in Nagaoka City, Niigata Prefecture. Enlarged detail (2 km x 1.3 km) of Figure 1.

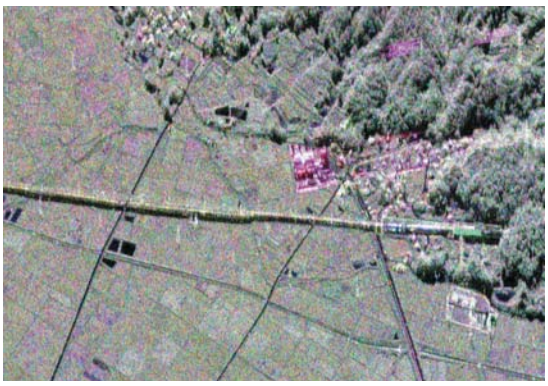

Figure 3: Exit of Joetsu Shinkansen Takiya Tunnel in Nagaoka. Enlarged detail (1.4 km x 1 km) of Figure 1. Shinkansen's elevated railroad runs in the middle of this picture. The derailed train is located to the left.

On the evening of October 23, 2004, a major earthquake with a maximum seismic intensity of 7 (Japanese scale) struck the Chuetsu region in Niigata Prefecture. Powerful aftershocks followed in Yamakoshi Village and other municipalities located around the quake epicenter. This serious disaster destroyed many houses, caused landslides, and claimed more than 40 lives.

As a means to assess the situation at the time of disaster as well as to keep track of the global environment, NICT has been developing airborne imaging radar capable of observing the Earth's surface at high resolution at any time of the day or night, regardless of weather conditions. To verify the relevant applied technologies, we are carrying out active research in collaboration with external researchers we recruited specifically for this purpose.

As described below, this airborne imaging radar can observe the Earth's surface at a resolution of 1.5 m from an altitude of 12,000 m at any time of the day or night, regardless of weather conditions (for more information, see CRL News No. 331, athttp://www2.nict.go.jp/kk/e412/CRL_News/0310/frame/002_flame.html). At the time of the volcanic disasters in Mount Usu and Miyake Island in 2000, we periodically observed surface features and the volcanic craters despite the eruptions and bad weather, and provided the organizations concerned and the general public with our observation results, which proved helpful in understanding and keeping track of the disaster conditions.

Since news reports indicated serious damage following this earthquake, we immediately made the relevant preparations, conducting observation of the afflicted areas by the 26th, three days after the quake occurred, subsequently releasing the observation images to the organizations concerned, the media, and the general public.

Figure 1 shows the area around the epicenter of the first principal quake. Figures 2 and 3 are enlarged details of Figure 1: a landslides site and the derailed bullet train are visible. We provided these and other pictures to the government's disaster headquarters and other organizations. In doing so, we hope to have made a contribution to area recovery efforts. These pictures are available to the public on our website, the address of which is indicated below.

We are developing the techniques to use these pictures to assess disaster conditions in sufficient detail. We are thus aiming at further improvements to the system, in collaboration with experts in civil engineering and disaster prevention.

This observation data is available on our website (address shown below). You can use it freely to analyze the disaster conditions if you wish to join us in contributing to the recovery efforts.

We extend our heartfelt sympathies to those in the areas affected by the Niigata Chuetsu Earthquake. We extend our hopes for the earliest possible recovery from this disaster.

You can see airborne SAR images of the quake-stricken areas at:
http://www2.nict.go.jp/dk/c215/PI-SAR/niigata_jishin.html