The need for high resolution mapping of the earth’s surface, more accurate atmospheric sounding data, soil moisture and vegetation mapping on the earth’s surface and their seasonal variations will soar considerably.

- Science instrument data rates will be in the range of 1 Gbps to 45 Gbps. Even with advanced compression algorithms (10:1 to 100:1) the satellite down link data rate will be in the range of 1 Gbps to 10 Gbps.

SDNITS is designed to serve the data transport needs of many satellites in different orbits, simultaneously transmitting to the designated destinations.
Video EESS Workshop

Courtesy of Charlene Chen and Ralph Cager, ASRC Aerospace Corporation

22 July 2003

IGARSS03
SDNITS Preliminary Concept

Crosslink Communications Between SDNITS & EO Satellites

Crosslink Communications Between EO Satellites

Communications Between SDNITS & Ground Stations

SDNITS Orbit

EO Orbit

SDNITS

EO: Earth Observation

Shadowed by Earth
### SDNITS Orbit

#### Low Earth Orbit (LEO)
- There may be several consecutive User satellite orbits before the SDNITS is seen consequently the onboard storage required may be large.
- Visibility time of the SDNITS from the User satellite will be short hence a very high data rate system must be installed on the User satellites.
- To make the visibility times larger, many SDNITS satellites will be required in the system making it expensive.
- Depending upon the orbits of User and SDNITS, the cross velocity between them may be high making the pointing of User antenna a difficult task resulting in loss of gain.
- The range between the User satellite and the SDNITS will not be great and hence less onboard telecom power will be needed for transmission.
- Easy servicing of the SDNITS and less expensive.

#### Geo-Synch Earth Orbit (GEO)
- The User satellite will see the SDNITS in its every orbit and has an opportunity of downloading the data. Thus the storage need is not large.
- Visibility time of the SDNITS from the User satellite will be long hence a relatively low data rate system will be needed on the User satellites.
- At most 3 SDNITS will be needed to provide almost perfect coverage for the User satellites. The cost will be held down.
- The cross velocities between the User satellite and the SDNITS will be lower and hence the pointing of User antenna would not be excessively difficult.
- The range between the User satellite and the SDNITS will be at least equal to GEO altitude making more onboard telecom power necessary for transmission.
- Servicing of the SDNITS will be expensive.

### Selected SDNITS Orbit: Geo Synchronous Earth Orbit
To select the orbit of the SDNITS and facilitate the design of SDNITS telecom system following orbital parameters are evaluated.

- Compute EIRP for SDNITS and User S/C
- Compute data volume for SDNITS
- Compute Doppler parameters
Maximum Range Computations

Maximum Distance Between Two Coplanar Elliptical Orbits.

Max Range = $\sqrt{[a_n(1+\varepsilon_n)]^2 - r_p^2} + \left\{ a_n(1+\varepsilon_n)^2 \left[ 2a_u\varepsilon_u r_p^2(\varepsilon_u^2 - 1) + a_n(1+\varepsilon_n) \left[a_u^2(\varepsilon_u^2 - 1) + \varepsilon_u^2 r_p^2 \right] \right]^2 \right\}^{1/2}$

$a$: major axis; $r$: radius of planet; $\varepsilon$: eccentricity of orbit
Maximum Range Results

SDNITS is in a Circular Orbit

User S/C Circular Orbital Radius (km)

Maximum User S/C - SDNITS Range (km)

SDNITS = 7000 km
SDNITS = 10000 km
SDNITS = 15000 km
SDNITS = 20000 km
SDNITS = 30000 km
SDNITS = 42242 km

Maximum Range Results

Maximum User S/C - SDNITS Range (km)

SDNITS = 7000 km
SDNITS = 10000 km
SDNITS = 15000 km
SDNITS = 20000 km
SDNITS = 30000 km
SDNITS = 42242 km

User S/C Circular Orbital Radius (km)
Ground Visibility

Pro-grade Node

Eccentricity = 0.0

a = 10000 km

Eccentricity = 0.0, 0.1, 0.2, 0.3

Retro-grade Node

Eccentricity = 0.0

Eccentricity = 0.3

g

\( y = mx + c \)

\( A(x, y) \)

\( B(x, y) \)

\( C \)

\( G(x, y) \)

Prograde Satellite

Eccentricity = 0.3

Retrograde Satellite

Eccentricity = 0.0

a = 10000 km

Eccentricity = 0.0, 0.1, 0.2, 0.3
SDNITS Ground Visibility Computation

Antenna Foot Print

Circular Orbits
- Purple: Orbital Radius = 42242 (km)
- Blue: Orbital Radius = 30000 (km)
- Red: Orbital Radius = 20000 (km)
- Magenta: Orbital Radius = 10000 (km)
- Green: Orbital Radius = 7000 (km)

Satellite Location Angle Phi (Deg)

Average Foot Print Diameter (km)
- $a=42242$ km, $e=0.0$
- $a=42242$ km, $e=0.2$
- $a=42242$ km, $e=0.4$
- $a=42242$ km, $e=0.6$
- $a=42242$ km, $e=0.8$

Orbital Radius = 42242 (km)
Orbital Radius = 30000 (km)
Orbital Radius = 20000 (km)
Orbital Radius = 10000 (km)
Orbital Radius = 7000 (km)

Satellite Location Angle Phi (Deg)

Antenna Pointing Angle Beta (Deg)

Foot Print Diameter (km)
Ground Station Antenna Elevation Angle

Elevation angle rate indicates Ground antenna structural stresses
Doppler and cross velocity experienced by the satellites

Doppler Velocity

Two different cases of rotational Doppler velocity experienced by the satellites
SDNITS Possible Concept

Communications Between SDNITS & User Satellites

Orbit 1

Orbit 2

Communications Between SDNITS & Ground Stations

SDNITS
SDNITS Possible Concept

User #N

Beam #N

Multiple Beams

User #2

Beam #2

User #1

Beam #1

Laser Com

SDNITS
Single Lobe:

SDNITS Antenna Pattern
An Example of Beam Coverage

SDNITS Antenna Beam Overlap Geometry
SDNITS Antenna Coverage

```
Total Number of Beams

- 3 dB Down, Diam = 4 m
- 3 dB Down, Diam = 5 m
- 4 dB Down, Diam = 4 m
- 4 dB Down, Diam = 5 m

Rmax (km)
```
# Link Budget

## Desired Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired data rate</td>
<td>1 Gbps</td>
</tr>
<tr>
<td>User altitude (circular orbit, eccentricity = 0)</td>
<td>7000 km</td>
</tr>
<tr>
<td>SDNITS altitude (circular orbit, eccentricity = 0)</td>
<td>42242 km (GEO)</td>
</tr>
<tr>
<td>Desired bit rate of the link</td>
<td>1 Gbps</td>
</tr>
<tr>
<td>Desired frequency of the link</td>
<td>32000 MHz (Ka-Band)</td>
</tr>
</tbody>
</table>

## Calculated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum range between SDNITS and the user satellite</td>
<td>44642 (km)</td>
</tr>
<tr>
<td>Total EIRP required to support the desired 1 Gbps bit rate</td>
<td>106 (dBW)</td>
</tr>
<tr>
<td>SDNITS antenna Gain</td>
<td>60 (dB)</td>
</tr>
<tr>
<td>SDNITS antenna diameter required to provide 60 dB gain</td>
<td>4 m</td>
</tr>
<tr>
<td>User satellite antenna EIRP required to support the desired 1 Gbps data rate</td>
<td>46 (dBW)</td>
</tr>
<tr>
<td>User satellite transmitted power</td>
<td>20 (W)</td>
</tr>
<tr>
<td>User satellite antenna diameter required to support the desired bit rate of 1 Gbps using Ka-band frequency of 32000 MHz</td>
<td>0.8 m</td>
</tr>
</tbody>
</table>
Telecom Performance
Allowable Bit Rate Vs User S/C Semi-major Axis
SDNITS at 42242 km, e=0.0

(Coplanar Orbits)
Telecom Performance
User Antenna EIRP as a function of Total EIRP
SDNITS at 42242 km, e=0.0

(Coplanar Orbits)
3-SDNITS system will support NASA’s future missions data transport needs around the Earth.
Areas that need further studies:

- Large inflatable high frequency antennas.
- Multiple beam forming antennas.
- Traffic Analysis
- Protocols
- Cloud cover, time available for transmission for laser communications link to the ground station.
- Software simulating the entire system.