Mobile Sensor Network for Supporting Autonomous Navigation (MSNA)

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Overview

- Motivation
- Components of MSNA
- Distributing sensing and processing
- Key challenges in designing MSNA
- Advanced sensors for mobile and stationary nodes
- Wireless communication networks
- Web services
- Mobile computing, communicating, consumer electronics convergence (MC4) device
- Implementation approaches and demonstration

Motivation

- Urban route planning and navigation
- Urban mapping and auto assist
- Collision detection and avoidance - ground vehicles, helicopters, trains
- Monitoring and surveillance
- Missile defense - a breakthrough approach using 3D Flash Ladar


270
495
267
29
Snow
blockage
295
Start
From
Maryland
Destination
1
201
Congestion
washington dc
66
110
50
395
Traffic accident
95
Image © 2006 TerraMetrics
Image © 2006 Sanborn

VW Golf

CMU's Sandstorm at DGC2

2007 Lexus LS 460L


Map View
Work
66
12
LEXUS

Intelligent Parking Assist in LS 460L

- Intelligent Park Assist (IPA) parks with just a little brake work.
- Electronically controlled brakes (ECB), EPS, VSC (vehicle stability control), ABS, Brake Assist (BA) and EBD (Electronic Brakeforce Distribution).
- Actuators for steering, throttle, and brake -Electric power steering (EPS)
- Sensors (sonar) in the front bumper
- Sensors (sonar and video camera) in the rear bumper
- Adaptive cruise control (ACC)

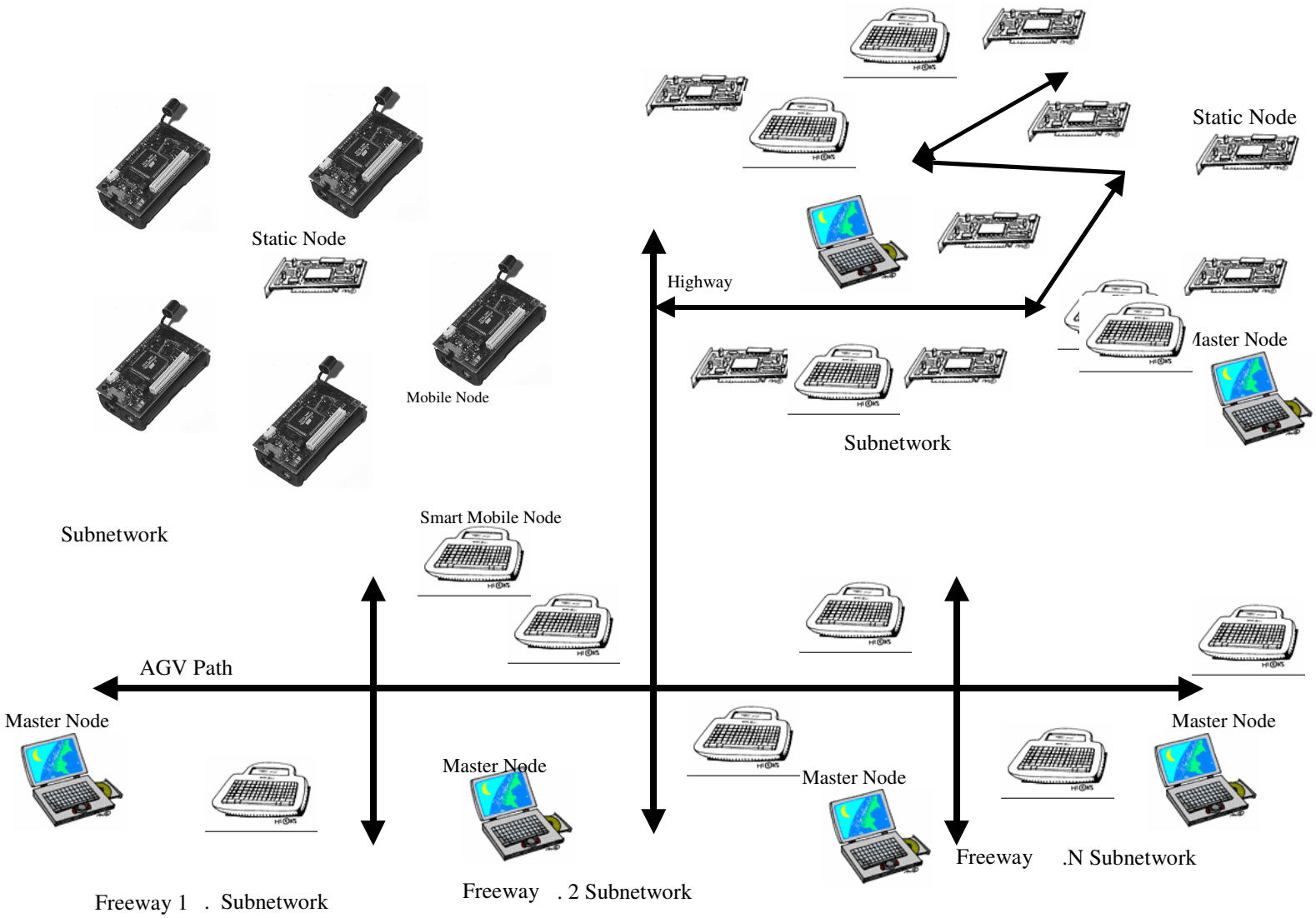
ACC in LS 460L

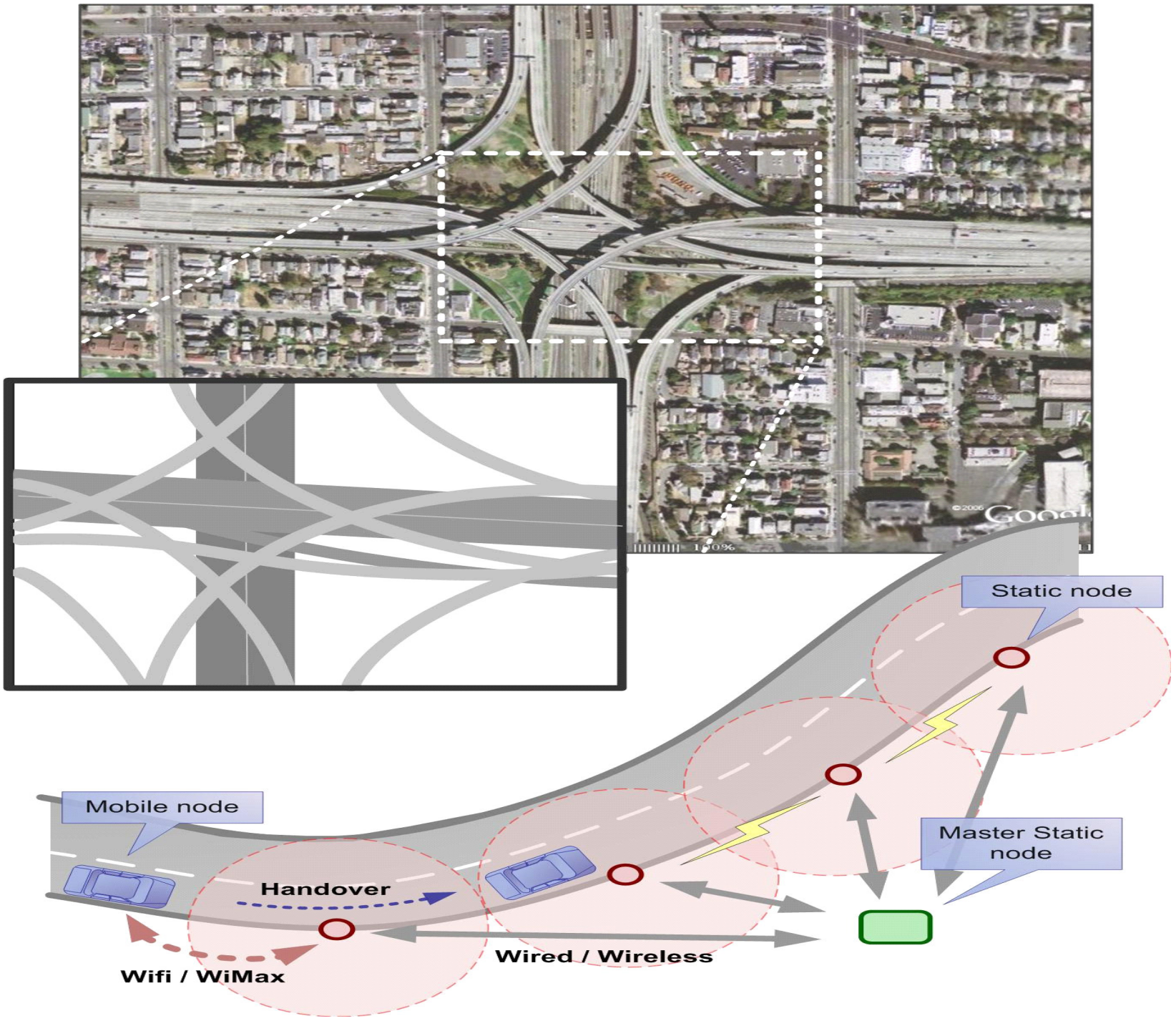
- The car has adaptive cruise control.
- It uses millimeter-wave radar to slow you if the car in front hits the brakes.
- If the system detects a collision, it'll add pressure to the brakes to help stop time, and electronically tighten seatbelts.

Components of MSNA

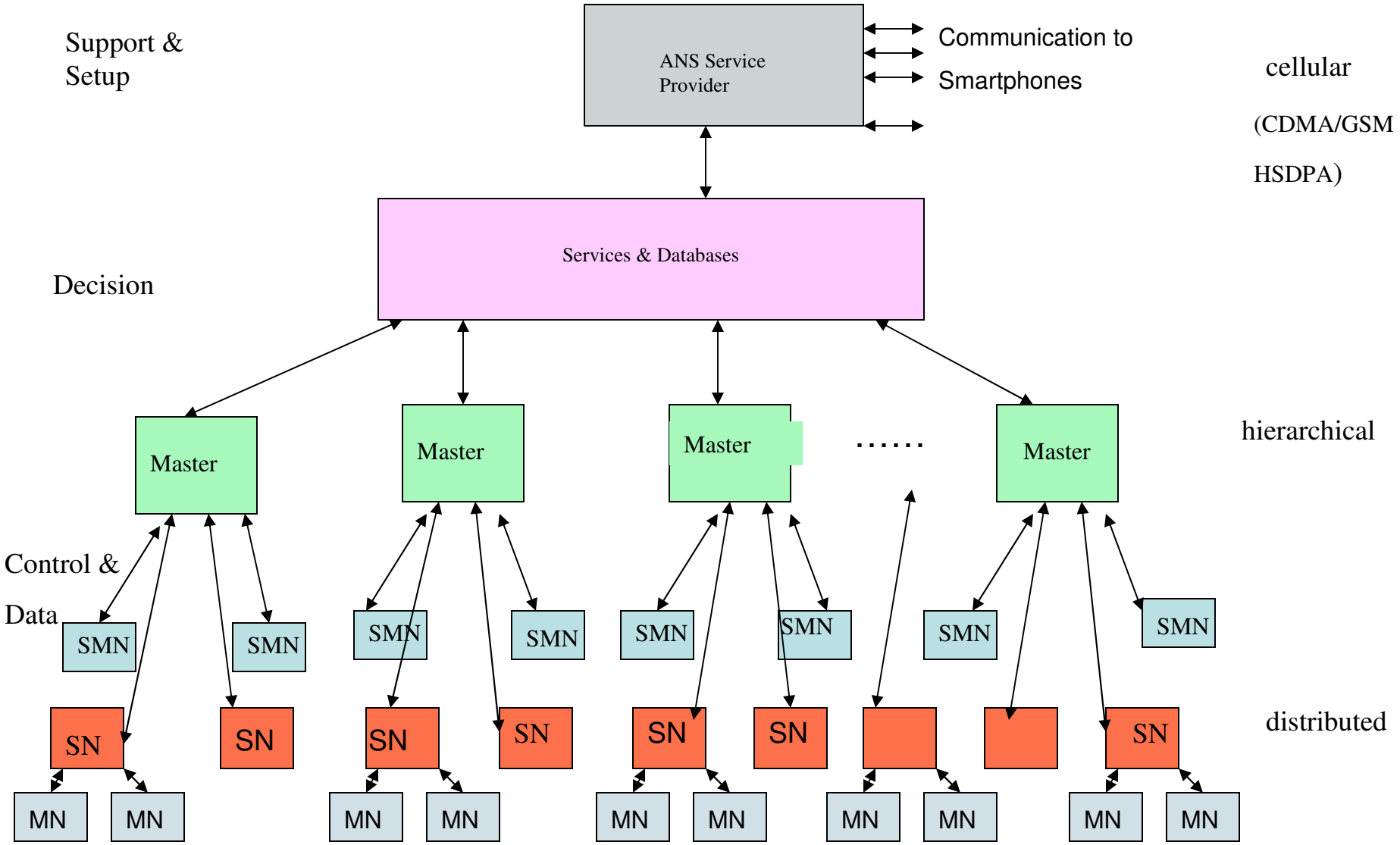
- Stationary nodes (SNs) or static nodes
- Master nodes (Masters)
- Mobile nodes (MNs)
- Smart mobile nodes (SMNs) – mobile nodes with advanced sensors
- Communication links (WiFi, WiMAX)
- Service providers and databases

Mobile Sensor Network for ANS




Static node
Mobile node
Handover
Master Static node
Wired / Wireless
Wifi / WiMax

MSNA Communication



Activities

- Status and setup activities - cellular network using CDMA/GSM or HSDPA
- Control activities - distributed using WiFi and WiMAX/DSRN
- Decision making activities - centralized using a hierarchical network based on WiFi, WiMAX, and cellular

SN Functions

- Receive IP address of MNs, SMNs from Master
- Establish communication with MNs and SMNs
- Update Master when MNs enter and leave
- Monitor position (range, lane, and speed) of SNs and SMNs
- Register vehicles that are not identifiable MNs, SMNs and their position
- Update master with unregistered vehicles
- Data exchange with MNs, SMNs, and masters

MN Functions

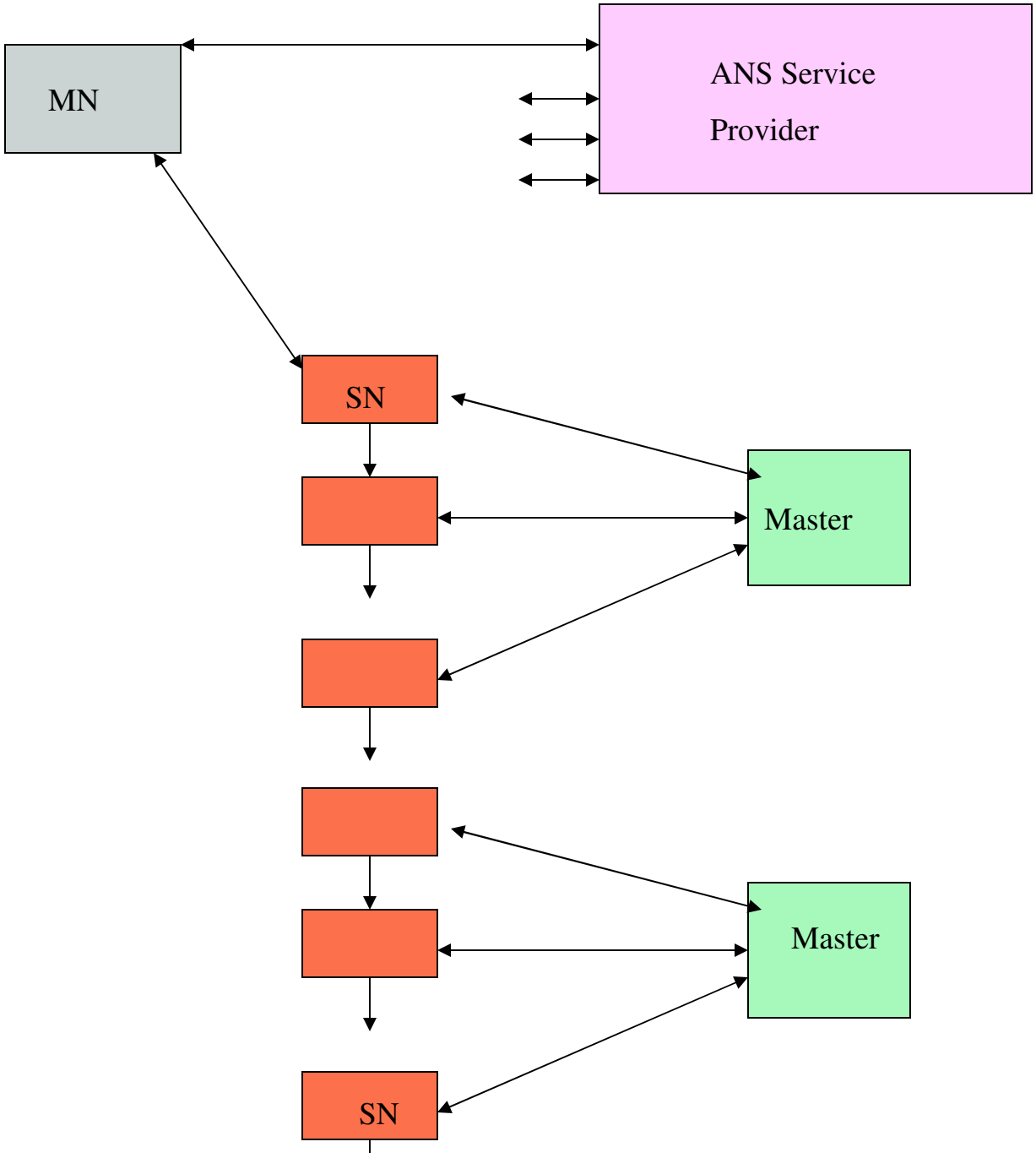
- Communicate IP and VIN to ANS service providers using cellular networks
- Communicate with SNs (entering and leaving) using WiFi
- Exchange data with SNs
- Communication from Masters using cellular network (emergency monitoring, news)

SMN Functions

- MN functions plus the following
- Communicate with Masters using WiFi and WiMAX.
- Exchange data with Masters and SNs

Master Functions

- Receive IP addresses and VINs of MNs and SMNs sent by ANS service providers using cellular network (first Master in the route does this)
- Communicate to SNs IP addresses of MNs and SMNs that will be communicating and expected time interval
- Communicate to other Masters routes of MNs and SMNs
- Handoff to next Master as MNs and SMNs move out
- Exchange data with SMNs and SNs and also other Masters
- Exchange data with databases and Service Providers


MN
ANS Service
Provider
SN
Master
Master
SN

Communication Between Nodes

- MN to SN – WiFi
- MN to Service Provider - Cellular
- SMN to SN – WiFi
- SMN to Master - WiMAX
- SN to SN - WiFi or wired
- SN to Master - WiMAX
- Master to Master - WiMAX
- Service Provider to Master - WiMAX or wired

Challenges

- Address allocation scheme
  - How will stationary nodes dynamically assign new addresses and pass it on to next stationary node?
  - What is the detailed addressing scheme (Sensor Network MAC address or IP/MAC with SSID or other)?
  - How can we map and maintain S/N address with dynamic IP address?
- Web service
  - What protocols to be used for real-time communication?
  - How can we integrate and handle request/result from many different systems?

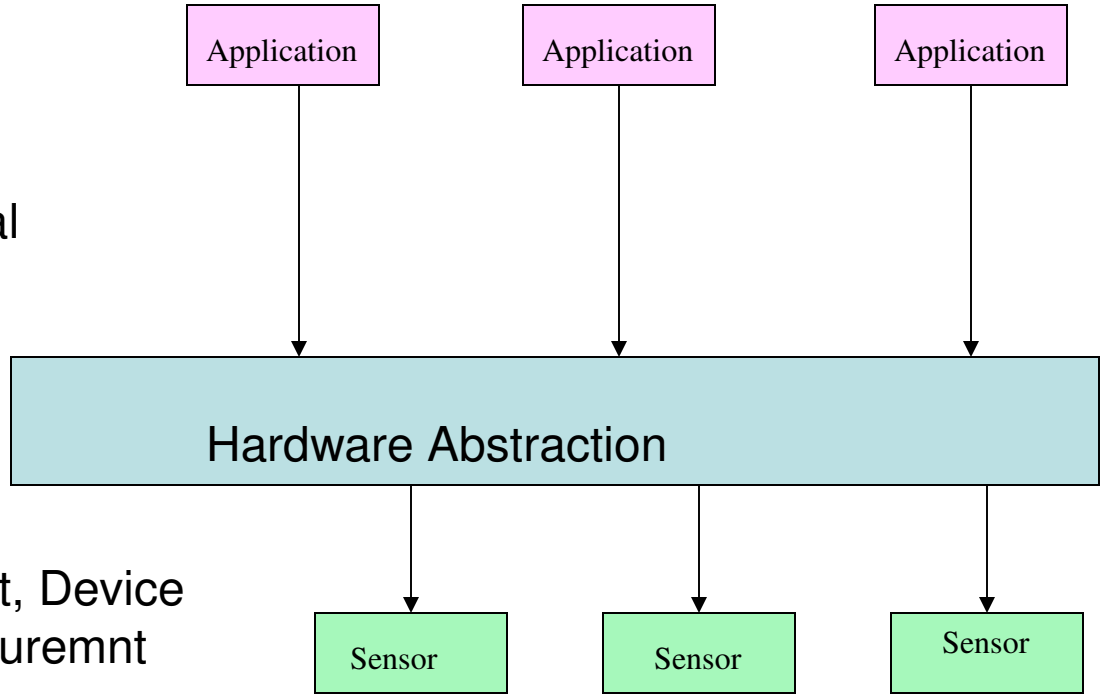
Challenges

- Security
  - What kind of user access control mechanisms will be supported?
  - How can we authenticate stationary node?
  - What happen if an attacker acts as one of the stationary nodes?
- Location information sharing
  - How can stationary nodes exchange location based information?
  - What is the protocol? What is the frequency of sharing? Do they have main DB?
  - What kind of query will be supported for spatial data?

ANS Approach

Environment constraint,

Computational complexity



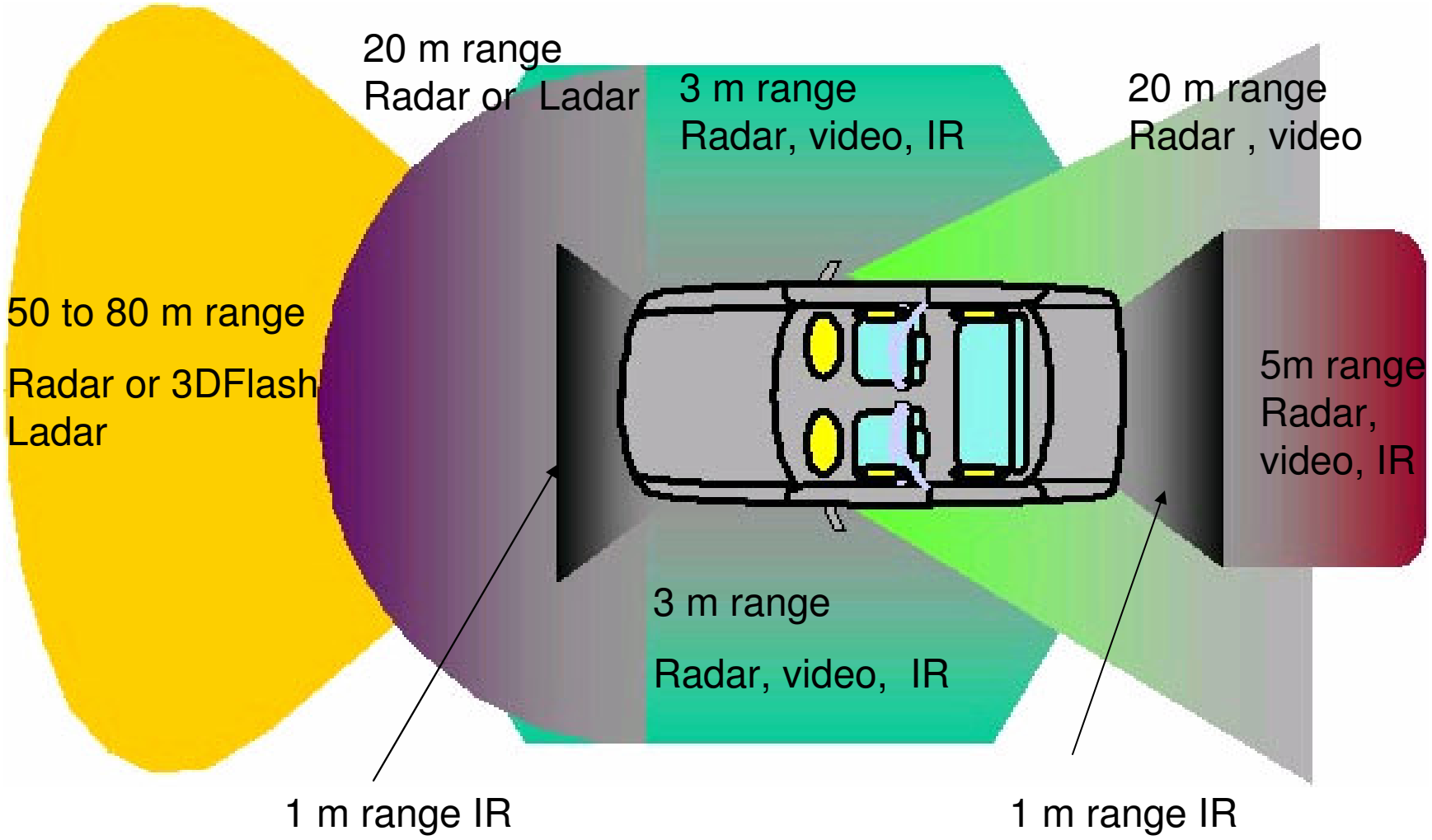
Sensor Device Drivers

Motion constraint, Device constraint, Measuremnt Uncertainty

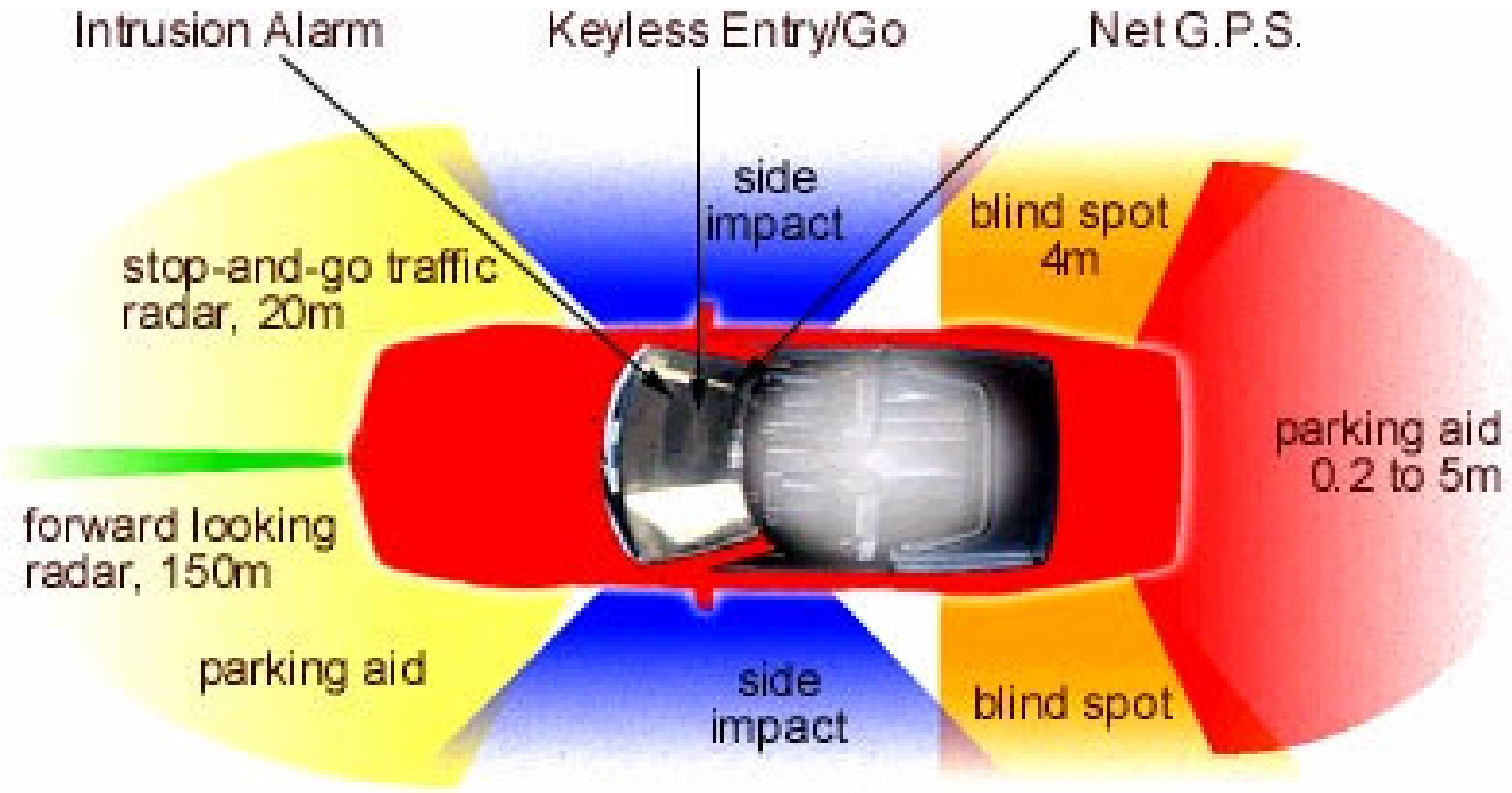
Advanced Sensor Classes

- Radar – mmw and Microwave
  - Eaton VORAD, Bosch, MACOM, ACFR
- Scanning 3D Ladar
  - Velodyne HDL-64E, BAE Systems
- 3D Flash Ladar
  - ASC
- Stereo combined with Sick ladar
  - Point Grey Research

Sensors for Mobile Node

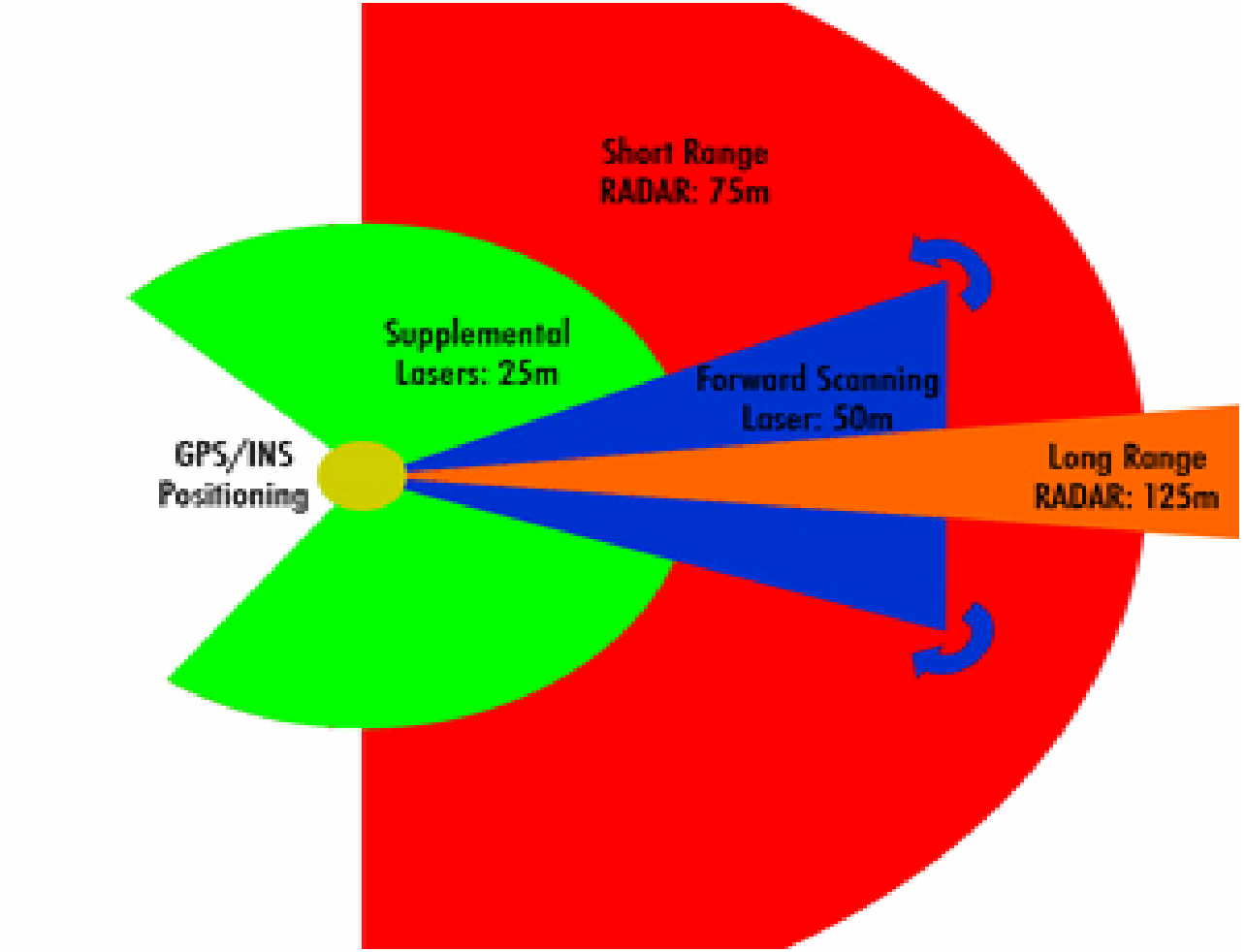


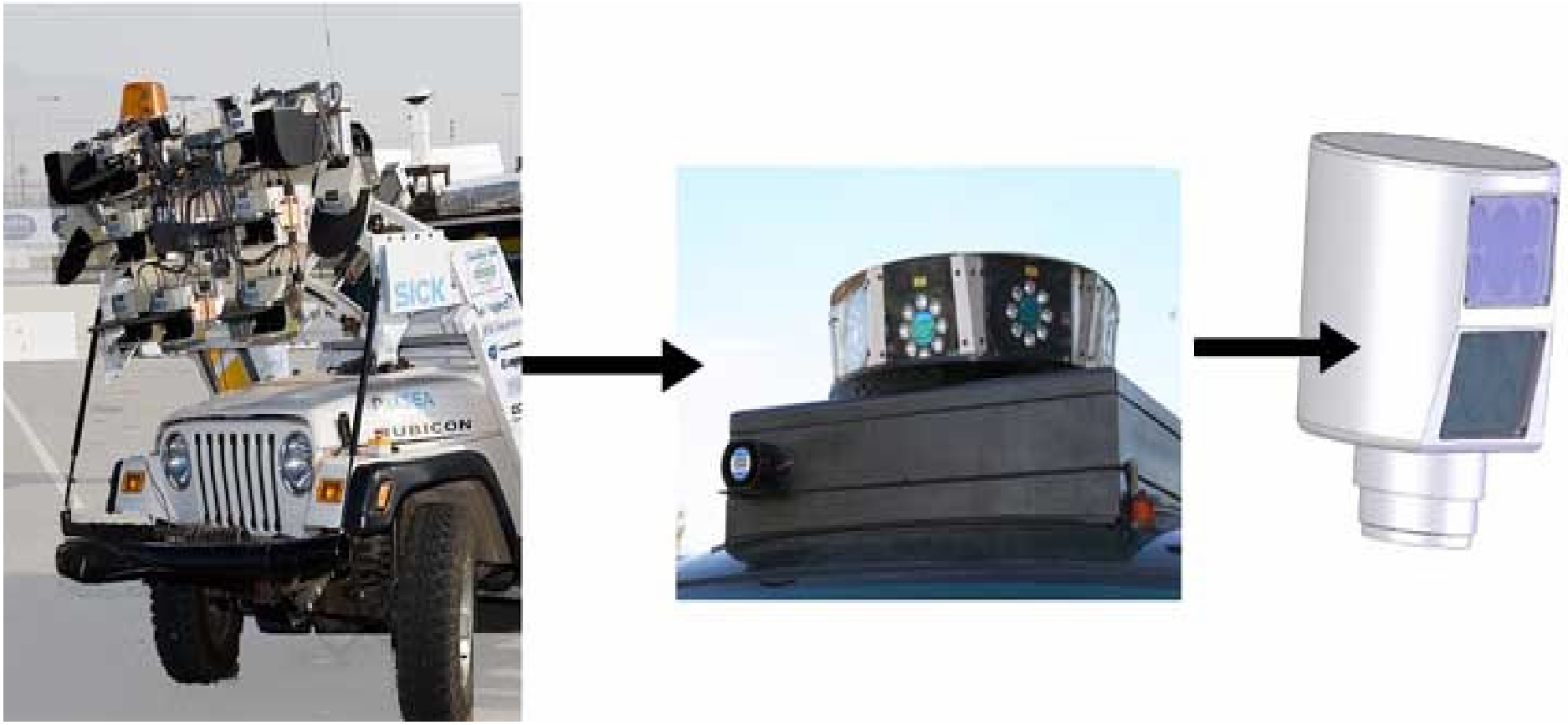
Multiple Sensors for Supporting ANS

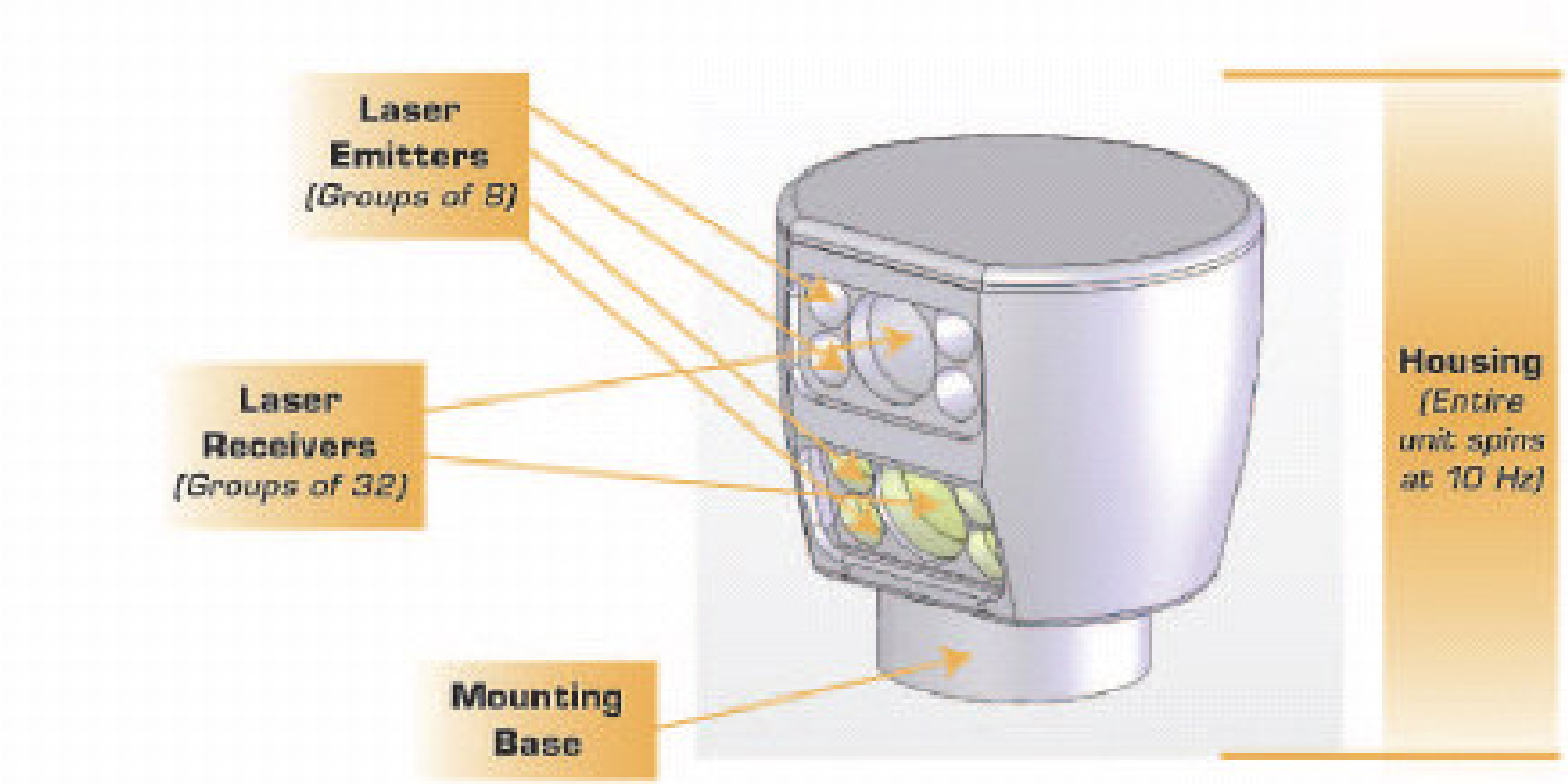


Radar

CMU Sensors for Off-road Condition




SICK
RUBICON


Laser
Emitters
(Groups of 8)
Laser
Receivers
(Groups of 32)
Mounting
Base
Housing
(Entire
unit spins
at 10 Hz)

Advantages of 3-D Flash Ladar: Size, Weight and Use is Consistent with Ordinary 2-D Camera

Hand Held .5 Hz 3-D Camera

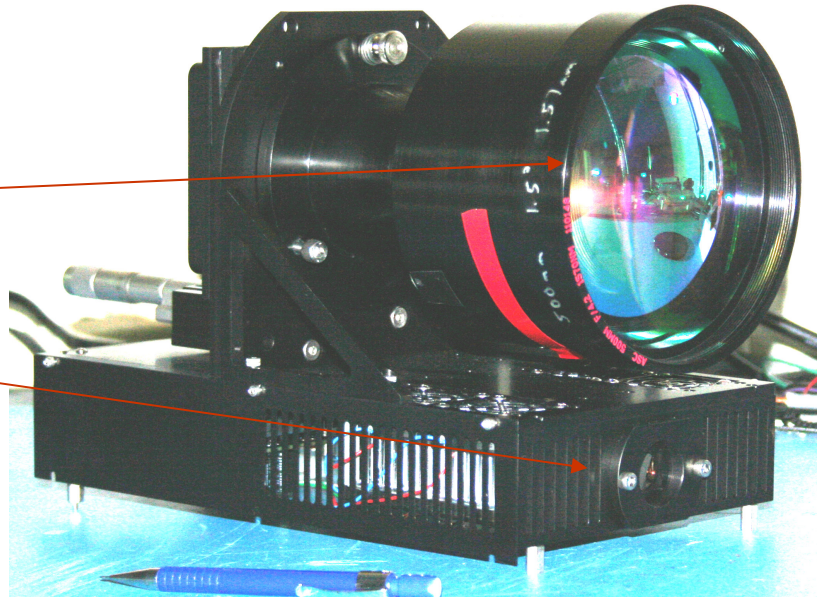
Laptop Processes and Displays 3-D Images

Controls Camera Functions

Receiver Aperture

Laser Transmitter Aperture

Hand Held 30 Hz 3-D "Video" Camera

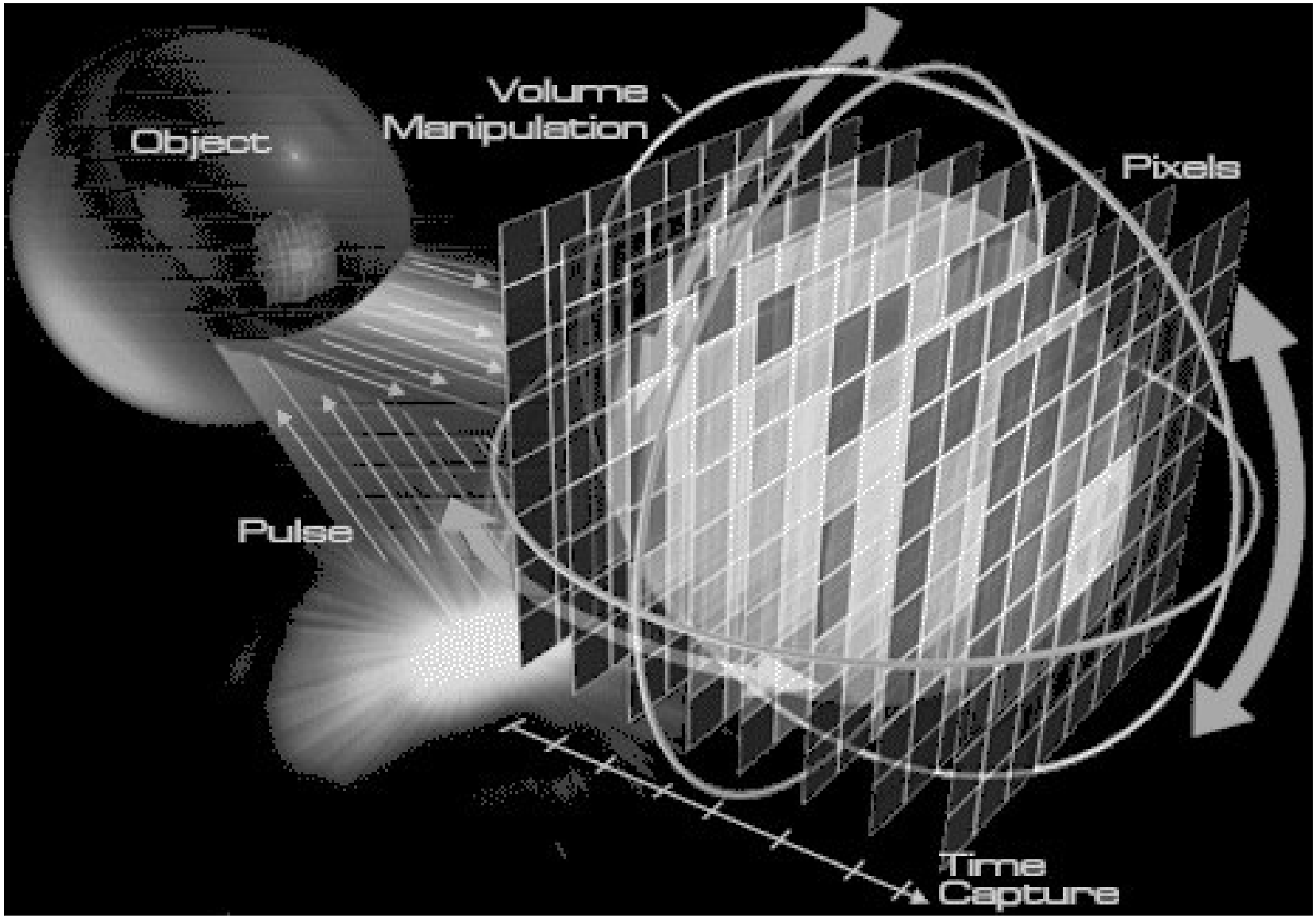


Modular Lens Substitution

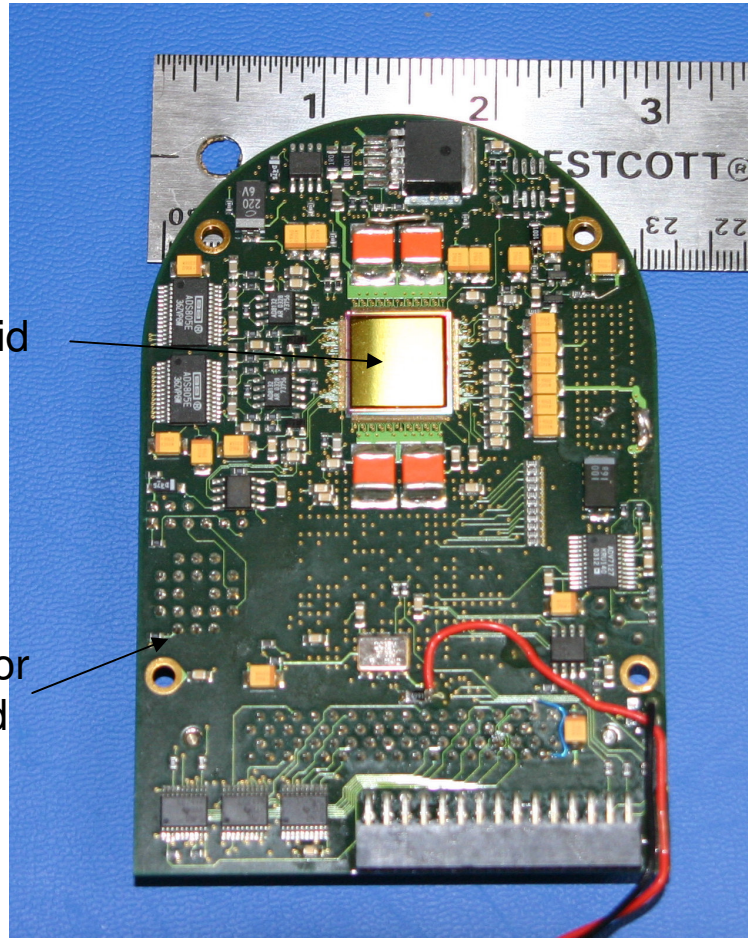
Kilometer Range

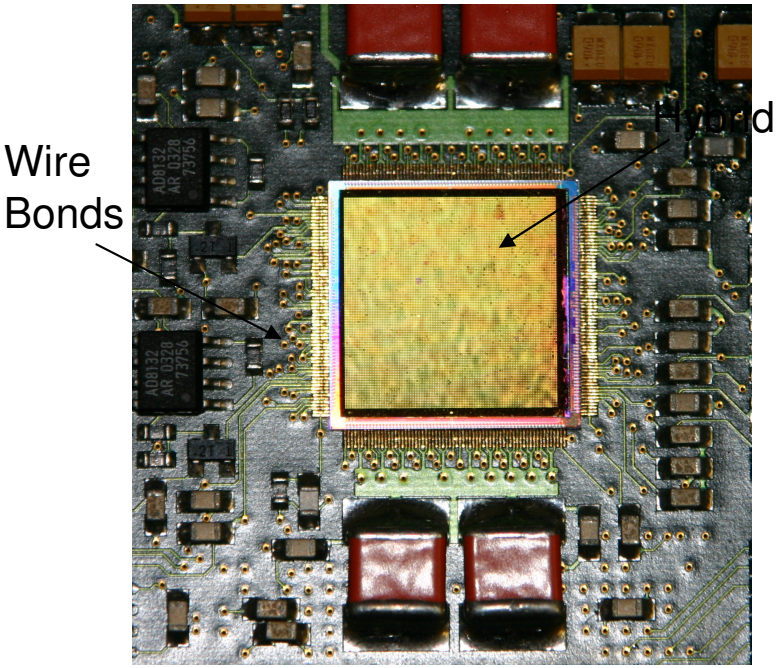
Conduction Cooled Laser

3D Flash Ladar

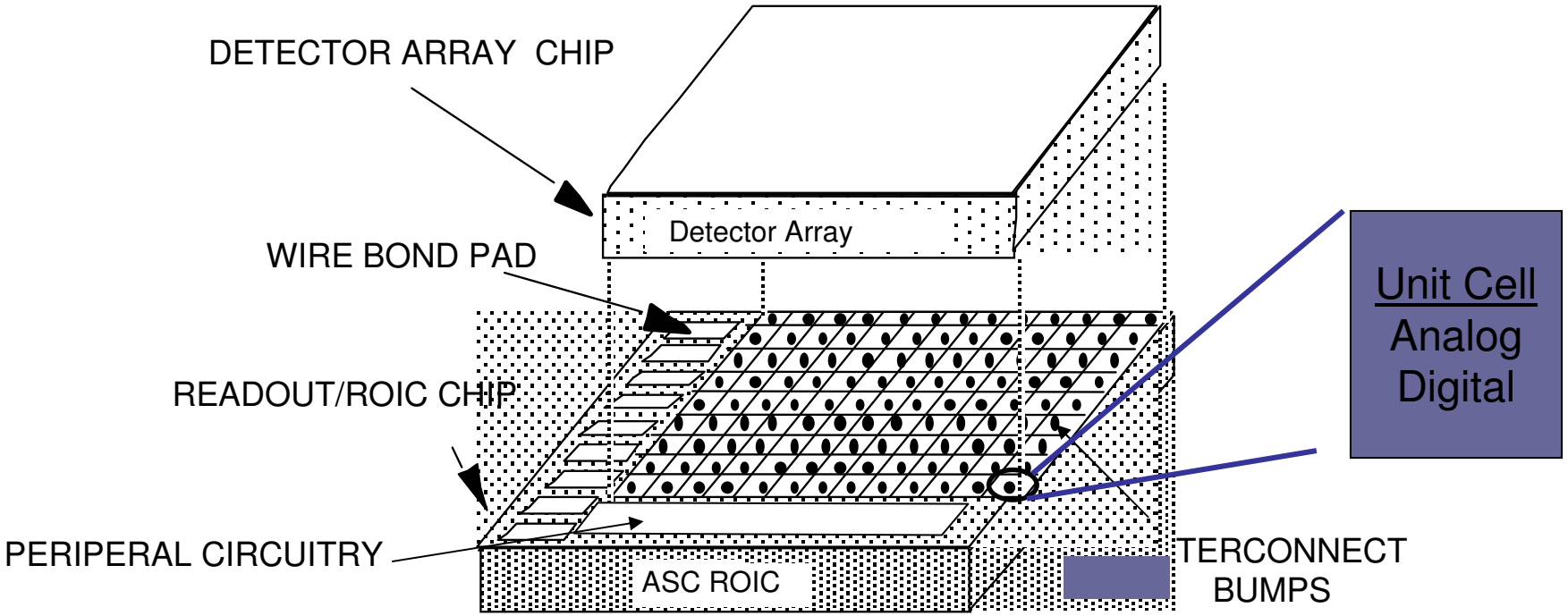


ASC 3-D Hybrid on Hand-Held Camera Sensor Board

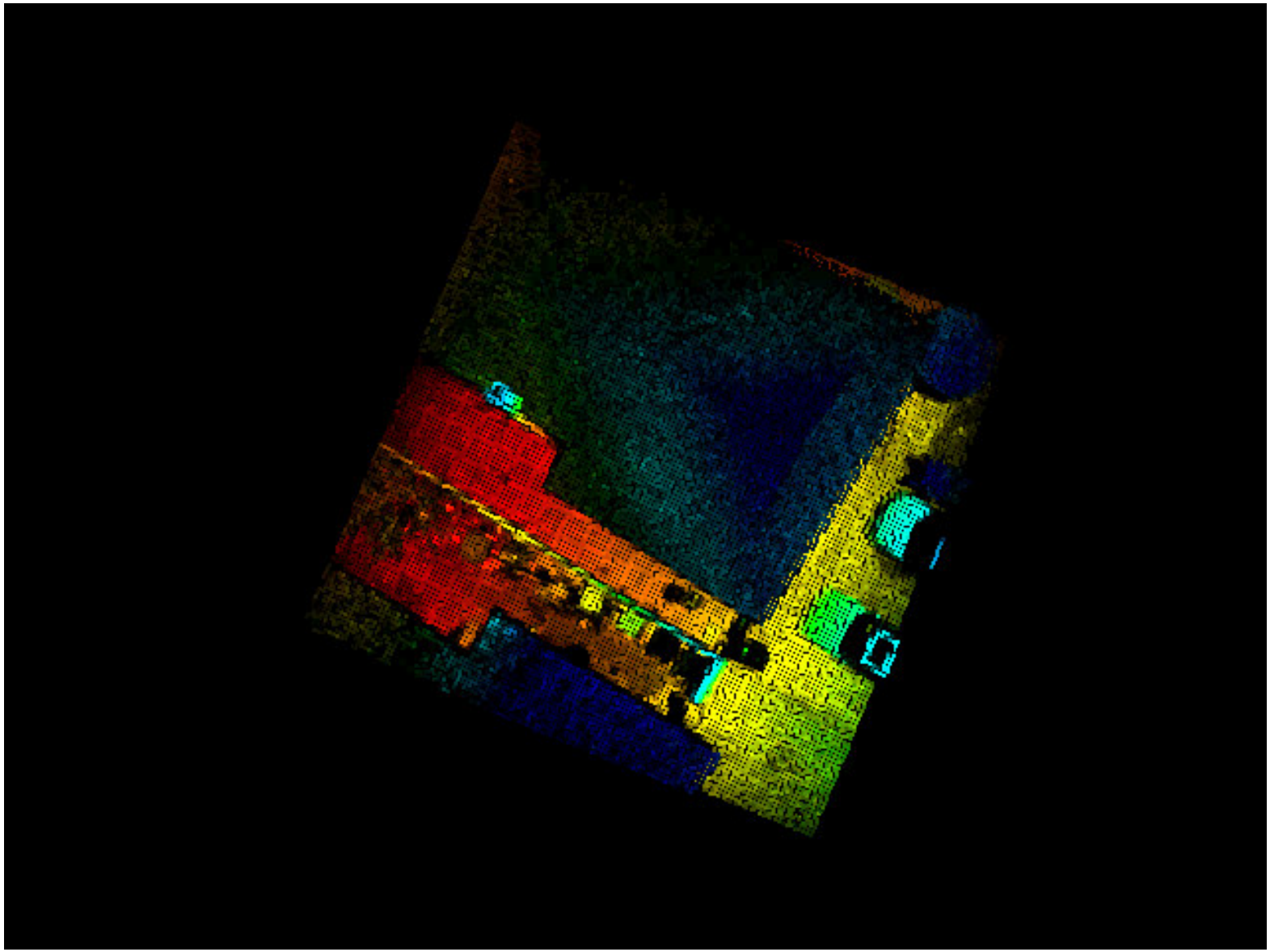




ASC HYBRID


DETECTOR ARRAY CHIP
Detector Array
WIRE BOND PAD
READOUT/ROIC CHIP
PERIPERAL CIRCUITRY
ASC ROIC
TERCONNECT
BUMPS
Unit Cell
Analog
Digital

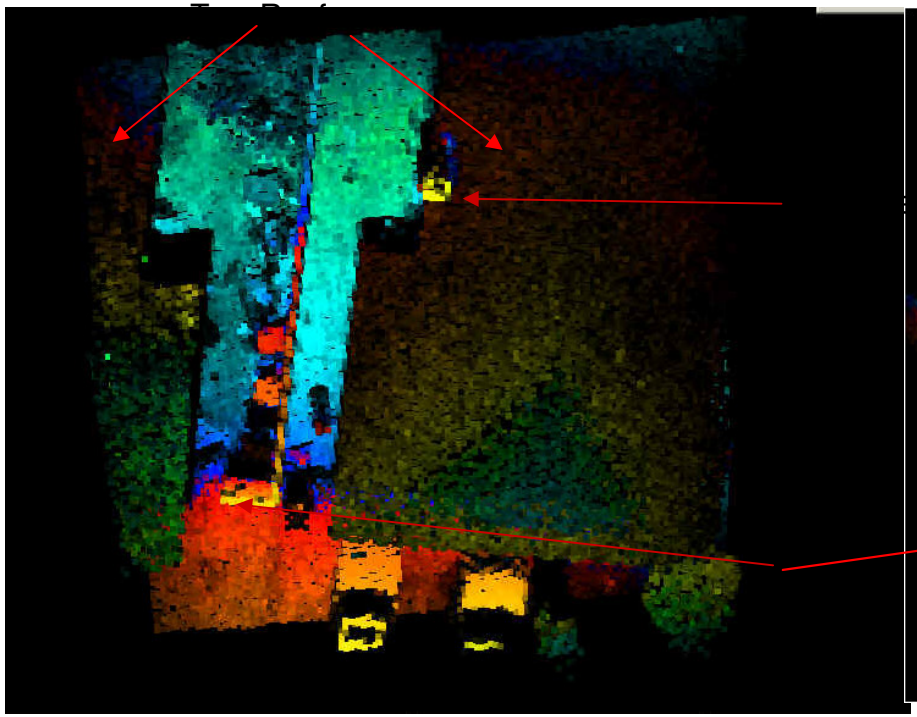
Flight Test at 1000 Ft Single Laser Pulse on 128 x 128 Array (Raw Data)



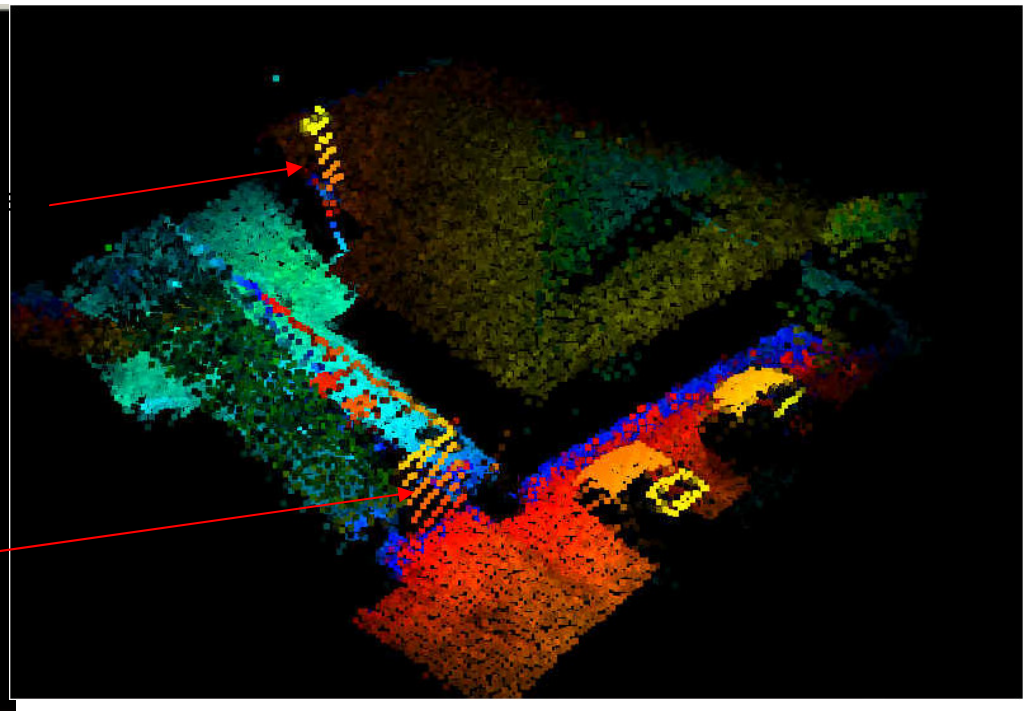
Flight Test at 1000 Ft Single Laser Pulse

128 x 128 Array (Raw Data)

No Image Enhancement Applied



Nadir 3-D Image of Two Roofs.
Color Denotes Range

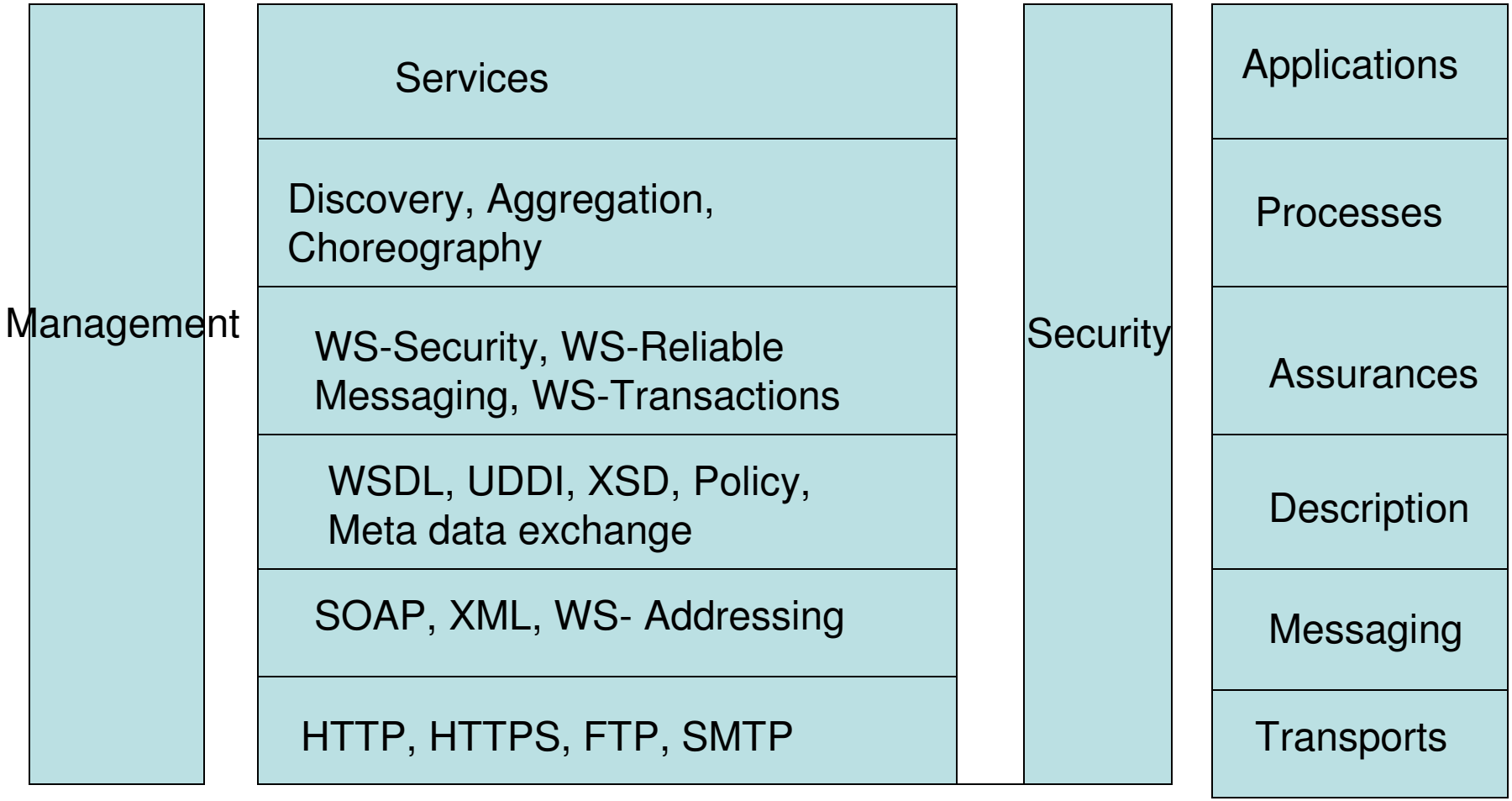


Rotated 3-D Image. Shows presence
of cyclone fence and automobile depth

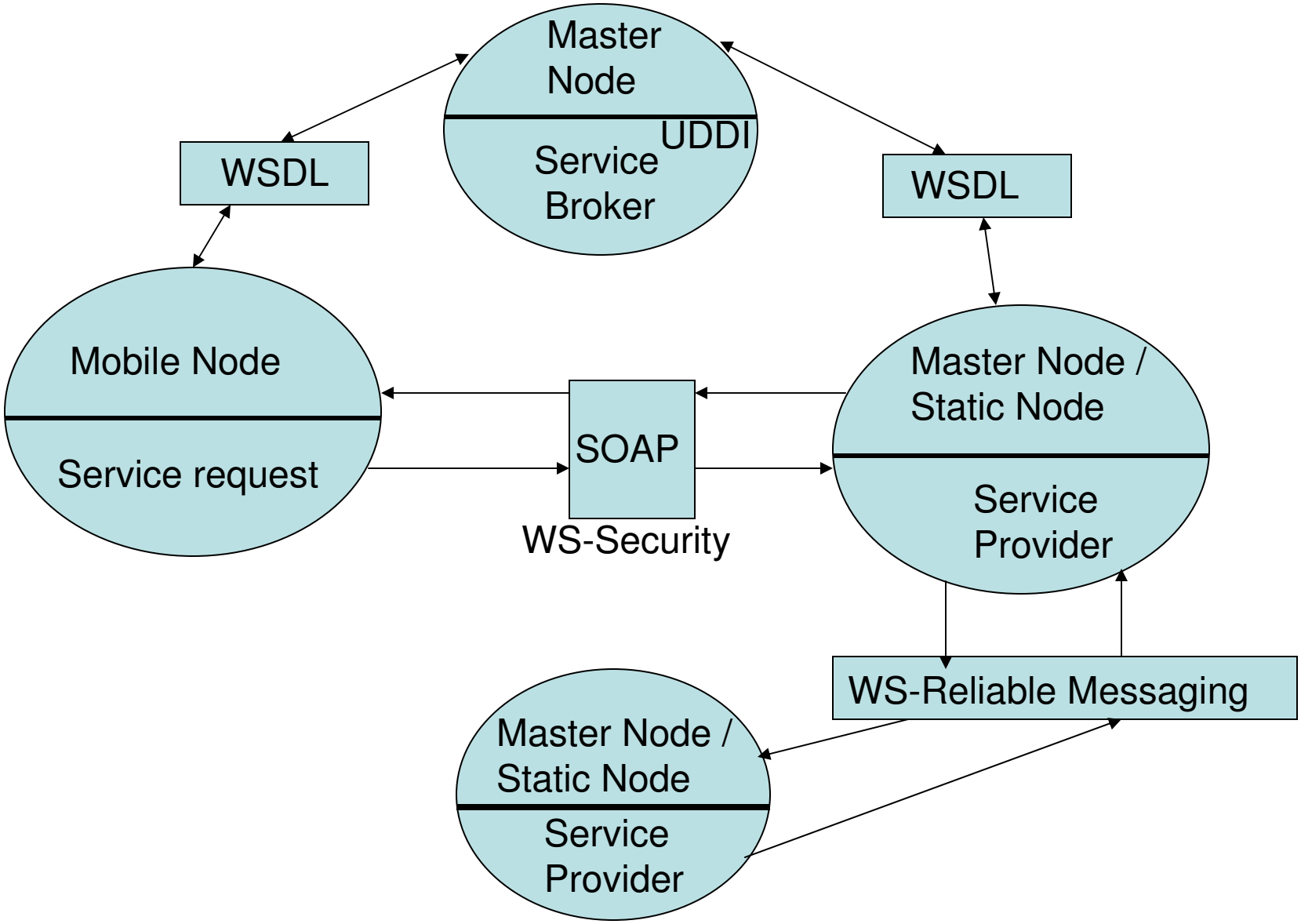
Wireless Networks

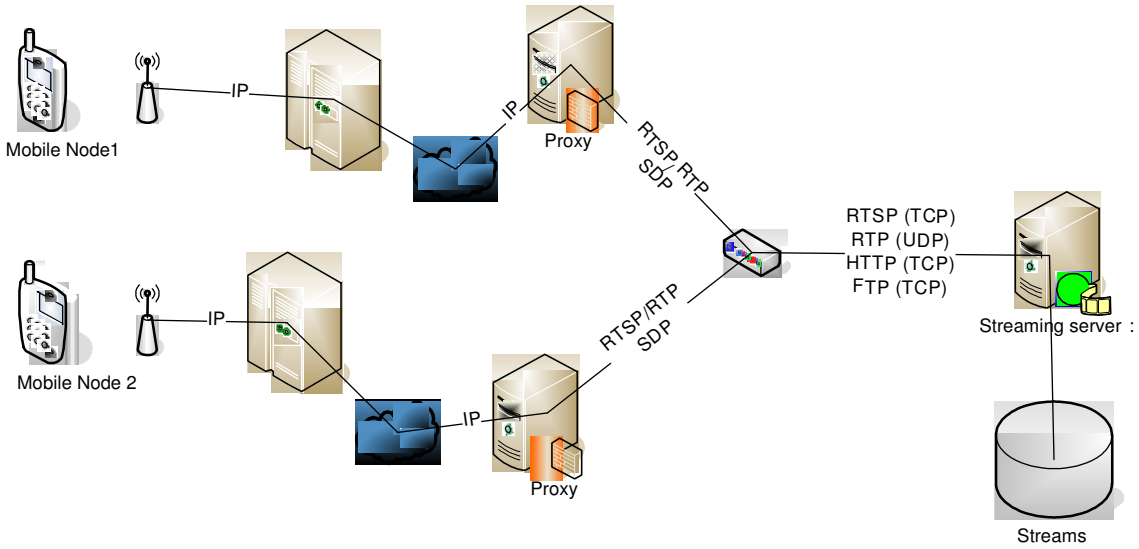
- WiFi with data rates in the tens of Mbps and range in a few hundreds of meters.
- WiMAX with data rates in the tens of Mbps and range in a few thousands meters
- Secure and trusted communication protocols
- Real-time communication protocols
- Cellular networks (CDMA/GSM, HSDPA)

Web Services Stack

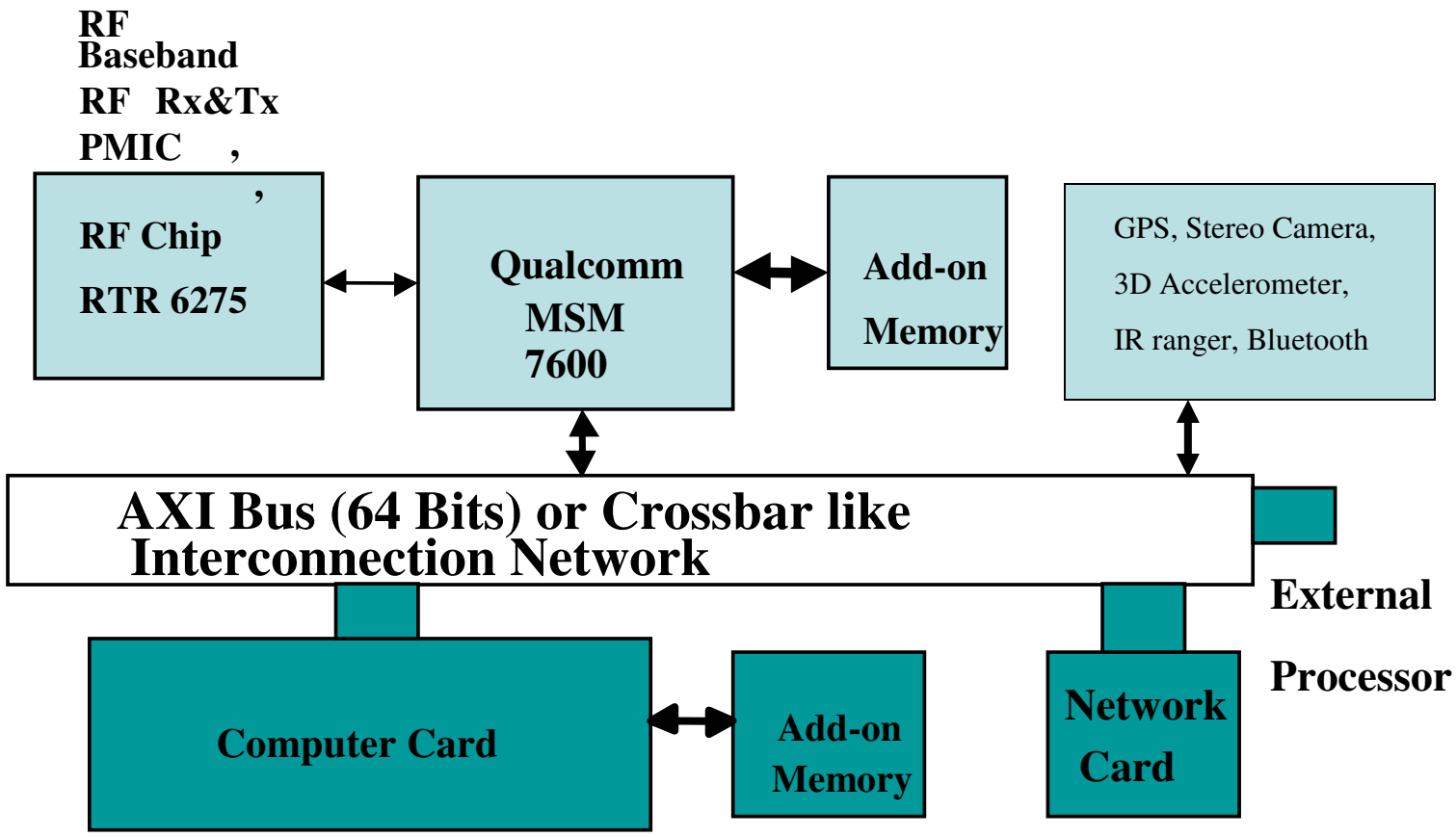


Web Service Request-Response




Mobile Node1
IP
IP
Proxy
RTSP/RTP
SDP
RTSP (TCP)
RTP (UDP)
HTTP (TCP)
FTP (TCP)
Streaming server :
Mobile Node 2
IP
IP
RTSP/RTP
SDP
Proxy
Streams

Mobile computing, communicating, consumer electronics convergence (MC4) Device



Implementation Approaches

- Service oriented architecture (SOA) and its implementation using Apache Axis2
- Services for global path planning, local path planning, lane following, perceptive passing, lane drifting alarm, collision detection, emergency video
- WiFi and WiMAX for communication involving stationary node (SN), mobile node (MN), smart mobile node (SMN), Master, and Service Provider
- Simulation using Orca2 and ICE


Navigation Technologies
SSC San Diego
JPL
Collision Avoidance, Stereo Vision
GPS Waypoint Navigation
USC
Simulation, Localization
CMU
Mapping, Localization
INEEL
Collision Avoidance
Mapping, Localization
SRI
Reflexive Teleoperation, Path Planning
SSC San Diego
6.2 TRANSITION PLATFORM
Motion Detection, Target Tracking
SSC San Diego
UCSD
Gyro-Enhanced Dead Reckoning
Univ. of MI
Cooperative Behaviors
SSC San Diego
6.3 TRANSITION PLATFORM
Ongoing Developments/COTS Upgrades
ATRV
ODIS
Packbot
TALON