John Deere *RGATOR* ™

Feb 18, 2009

Bob Norris

norriswilliamr@johndeere.com

w - 704-587-2909

C - 704-607-2742

Agenda

- **Design Concept**
- **Deployments**
- **System Capabilities and Missions**
- **Payloads**
- **Distinct Advantages**
- **Opportunities**

John Deere *RGATOR*

Design Concept

- **Operations in both manned and unmanned modes.**
  - **John Deere M-Gator basic mobility platform**
    - **Leverage existing logistics, maintenance, and training investments - Reduced cost and ease of deployment**
  - **Modes of operation – Manned, Tele-operation, GPS waypoints**
  - **Factory installed robotic capabilities without degradation of the basic M-Gator**
  - **M-Gator has military certifications as an air-droppable or air-mobile platform**
    - **R-Gator in its current form can/ but does not currently possess these certifications**
- **Missions of the *RGator***
  - **Remove users from hazardous missions, and ensure effective mission accomplishment**
  - **Serve as a host for payloads**
    - **Current configuration - payload space, 1400lb carrying capacity, auxiliary power available, limited power supply and ethernet or CAN interface for access to communications and internal system information**

John Deere *RGATOR*

Deployment - 5 Systems (2005 – 2008)

- **SPAWAR - user group uses *RGATOR* for Perimeter Defense Duty**
  - **Integration of EOIR & Radar sensor payloads for their application**
- **TARDEC - system was updated with Aware 2 and currently supported by iRobot**
- **NASA - uses *RGATOR* for research related to next Lunar Rover & Payload development**
- **RSJPO**

Basic Capabilities/ Modes:

- Manual
  - Operated by in-the-seat human control.
- Tele-Operation (Tele-Op) –
  - Direct or via camera
  - Operation performed with the remote operator control unit (OCU) or wearable computer using an X-Box 360 controller.
  - Operator assisted tele-operation
    - Directional Tele-operation
      - Using camera, point in a direction on the horizon and the system drives in that direction under its own control
    - Breadcrumb waypoint Tele-operation
      - Using camera feed, place waypoints in the viewed image and system will drive to those waypoints.

Basic Capabilities/ Modes:

- **Global Positioning System (GPS) Navigation**
  - Programmed to be controlled by user placed coordinates using Global Positioning System (GPS)
  - Operation independent of human intervention - system plans and travels from coordinate to coordinate
  - Map of the area used to help the user select waypoints
  - Operation performed with the remote operator control unit (OCU) or wearable computer
- **Teach and Playback –**
  - Route is collected from manual or tele-operative driving
  - Follows programmed route without human operation
  - Operation performed with the display computer unit (DCU) on the machine or the remote operator control unit (OCU) or wearable computer
- **Obstacle Detection and Avoidance –**
  - Programmed to recognize certain obstacles in its path and will avoid the obstacle and then resume its programmed route

Intelligent Vehicle Systems

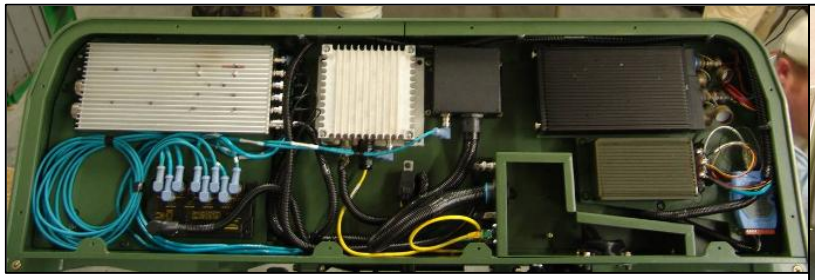
JOHN DEERE

- **Guiding an intelligent vehicle requires global perception, local perception and vehicle control**
  - **Global perception - localization and path planning system**
    - **Identifies the vehicle position with respect to an available global map and the path that the vehicle has to track**
    - **Vehicle has to know its position and direction with respect to real world and series of positions in order to reach the destination**
    - **Due to environmental dynamics, global perception system alone is not enough to maneuver vehicle to move to its destination.**
  - **Local perception**
    - **Real-time sensing system required to perceive vehicle's surroundings**
    - **Avoid static and dynamic obstacles that block vehicle path – requires localization accuracy to detect small objects and coherently image scanned data**
  - **Vehicle control system**
    - **Integrates information from the global and local perception systems then determines an appropriate action of the vehicle**

RGATOR

RSJPO *RGATOR*

JOHN DEERE



RGATOR

Localization System

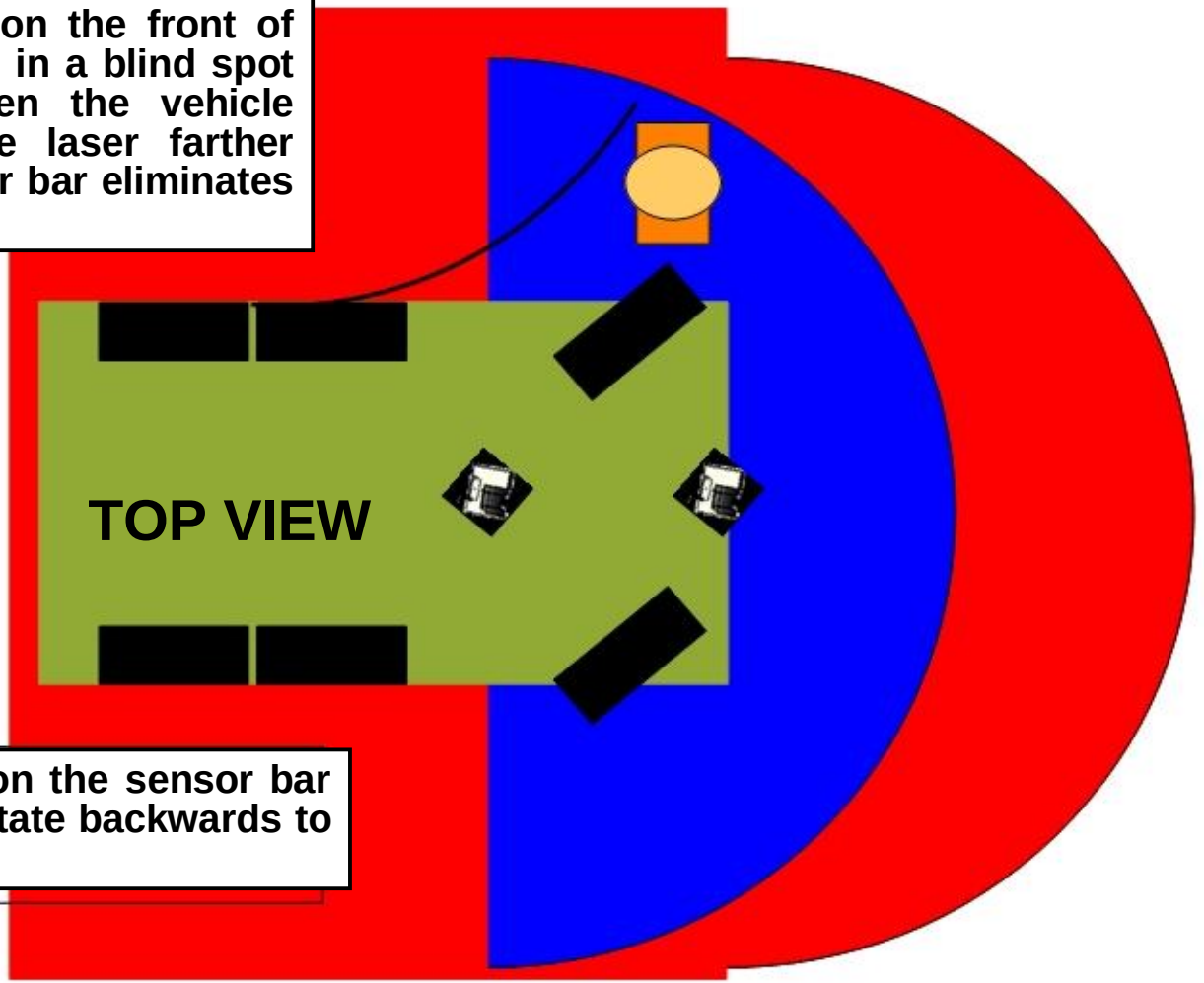
- **Global Localization feeds into Obstacle Avoidance <-> Obstacle Detection**
- **Challenges - sensor tuning for dead reckoning and reliability with GPS problems**
  - **“Trusting GPS” states (RTK (fix, float) & DGPS**
  - **Filtering bad position info. Using NMEA message stream.**
  - **More robust if solution were tightly or ultra-tightly coupled at the measurement level.**
  - **WAAS not always available in some areas of Northeast.**
  - **StarFire mode not used due to possible outages and startup issues**

Scanning vs Fixed Lasers

- More complex terrain or obstacles that require 3D data analysis for adequate performance
- Terrain with significant slope changes
  - Note that if the vehicle is moving fast, the laser may still be used as a “push-broom” detector, but the scanner will rotate the laser to hit the ground at the correct distance as the vehicle goes through rolling terrain
- Requirements to detect obstacles at different distances
  - Due to geometry, ditches can only be detected at short distances - For more optimal planning, want to detect taller obstacles far away
- Desire a system that can rescan an area and correct its mistakes and better handle dynamic obstacles

Mounting Location
Vehicle Coverage and Turning

Placing the laser on the front of the vehicle results in a blind spot to the sides when the vehicle turns. Placing the laser farther back on the sensor bar eliminates this blind spot.



Placing the laser on the sensor bar also allows it to rotate backwards to cover backing up

Scanner Configuration
180º+90º vs 90º+90º

- Both 180+90 and 90+90 configurations provide adequate point density, field of view, and time between scans
- 180+90 has following advantages
  - Mounting location - both lasers are facing forward and are symmetrical so they can be mounted above and below instead of side by side like required in the 90+90 angled in configuration
  - Flip-over capability - the single 180 laser can be flipped over to provide backward motion safeguarding. The 90+90 configuration would require both to flip over
  - Algorithm flexibility – Since both lasers are facing forward and symmetrical, one can be scanned and one can be used as a push-broom if that is desired (eg during high speeds on a road). The 90+90 angled in configuration doesn't support this type of operation since each is required to scan to cover the FOV

RSJPO Difficult Acceptance Criteria

- **Tested in saturation temperatures -10 º C to +60º C**
- **Detectable minimum size obstacles –**
  - **Minimum height 15 cm**
  - **Minimum width 5 cm**
  - **Negative – minimum depth 15 cm**
- **Plan around and bypass obstacles by 0.67 m**
- **Notify operator of obstacle with option to override**
- **Path following error less than 0.5 m under 50% canopy**
  - **(actual < 0.25m)**
- **24 hr run time with no direct human intervention**

  (120 hrs of unmanned evaluation before customer delivery)

  (SPAWAR system had 2000hrs of operation)

John Deere R-Gator
Missions

- **Missions – Payloads are Key**
  - **Reconnaissance/ Point Man**
  - **Remote Observation Post**
  - **IED/ Mine Detection**
  - **Marsupial – Remote deployment of smaller UGVs and UAVs**
  - **NBC Detection**
  - **Casualty Evacuation**
  - **Roving patrols/ Security**
  - **Transportation of ammo/ supplies**
  - …
- **Open to leveraging mission partnerships**

John Deere *RGATOR*

Future Mobility Platform

Intelligent system architecture lends itself to moving technology platforms

Gator 850D XUV 4x4 - Diesel

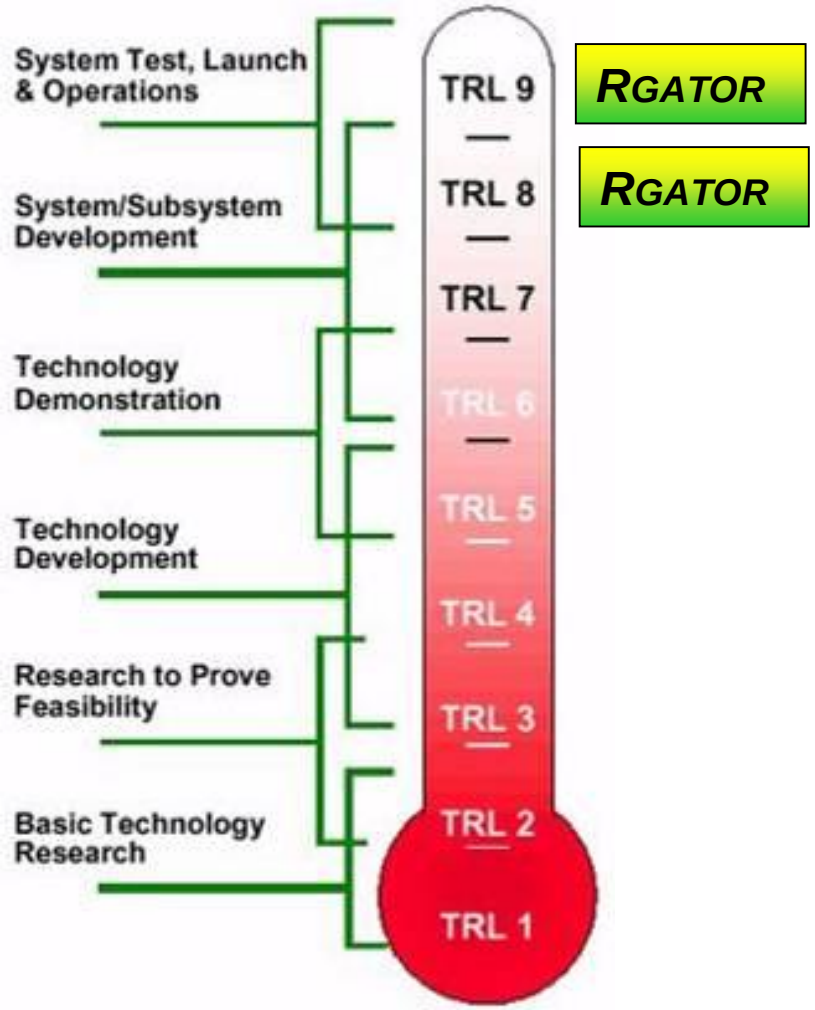
- **Independent rear suspension**
- **60-inch width and 113-inch**
- **1,383 pounds (with fluids)**
- **11” Ground clearance**
- **40 mph top speed and fast acceleration (Current 30 mph)**
- **Exclusive electronic governor and throttle for more power under load (EFI)**
- **On-demand, true 4WD for superior terrain capability**
- **Fording clearance as built 24” (air intake)**
- **Lifetime underestimate – 1400 lb payload**
- **Potential hybrid/ plug in hybrid/ fuel cell - 6x4 Gators already exist**

http://atvillustrated.com/node/252

John Deere *RGATOR*

Readiness

- **Readiness and Delivery**
  - **Readiness level**
    - **Vehicle chassis, drive-by-wire electronics are TRL 9 equivalent**
      - **5,000 M-Gators fielded**
      - **Over 20,000 XUVs sold**
    - **Remainder of system at TRL 8 equivalent**
  - **Small orders can be shipped in 3 – 6 months depending on mission packages**
  - **Large orders can be shipped in 6 months +**
  - **Delivery time can be accelerated**



John Deere *RGATOR*

Distinct Advantages

- **Technology works today**
  - Base technology ready – may need minor refinements
  - Potentially fills gaps – small and large robots, FCS
- **Low cost**
- **Reliability**
- **$20M in development costs already invested (Deere & Co)**
  - 15 robotic engineers
  - Dozens of supporting systems engineers, technicians etc.
- **World class service and support**
  - Logistics – 1.5 days worldwide
  - Dealers in theater
  - Ongoing field systems support
- **Payload/ technology flexibility**
  - Modular design
  - Communication architecture
- **Manually driven**
  - Easy to maneuver – loading, maintenance, etc
  - Drive to deploy where needed
  - Ease of recovery

Questions?