IntelliDrive^{SM} (VII) for Safety, Mobility and User Fee Implementation

Oral Presentation

to

Minnesota Department of Transportation

March 1, 2010

Presentation Outline

- Introduction and System Overview
  - System Design
  - Meeting Mn/DOT's System Requirements
  - Ability to Meet Critical Success Factors
- Information on Interview Topics
  1. Pricing Zones/Fee Structures
  2. Gathering Probe Data
  3. Use and Robustness of Cellular Phones
  4. Leveraging into State-wide, National, International
  5. Collecting Mileage Based User Fees
  6. Resources Adequate and Necessary
  7. Project Management Approach
- Question and Answers

INTRODUCTION TO THE BATTELLE TEAM

The Battelle Team

Battelle — *The Business of Innovation*

- Prime Contractor
- Lead systems design and integration, software development
- Production and deployment

URS

- Major Subcontractor
- Lead systems testing
- Lead integration with Mn/DOT ITS systems
- Manage Field Operations

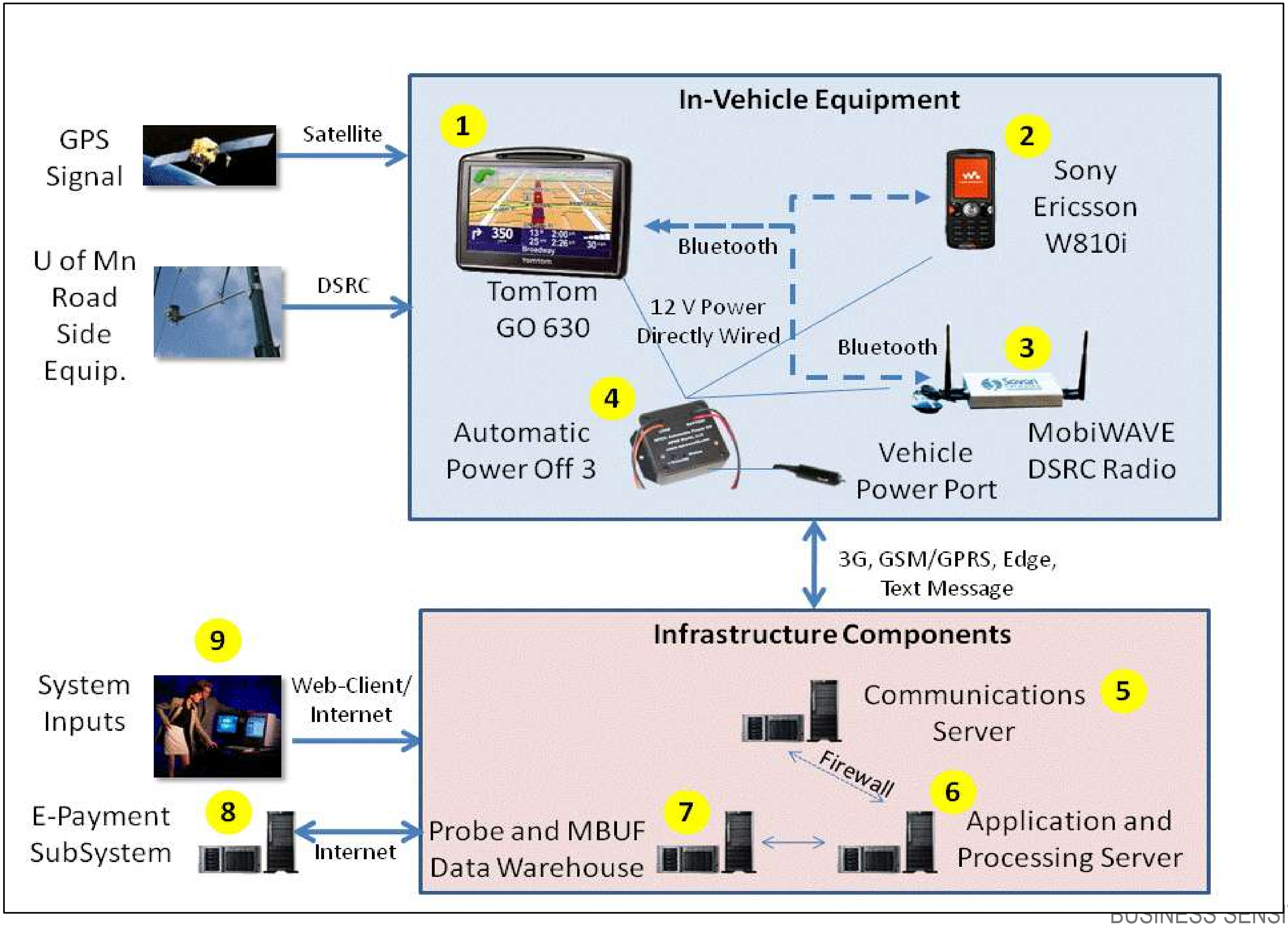
PIERCE PINI & ASSOCIATES, INC.

- DBE in Minnesota's Unified Certification Program
- Odometer readings, participant support

Symbiont, Inc. — An Information Technology Solutions Provider

- DBE in Minnesota's Unified Certification Program
- Equipment vendor
- Inventory tracking and management

Review of The Battelle Team's Innovative System Design



Meeting Mn/DOT's System Requirements

- Meeting Existing Requirements
  – Our design meets ***all*** mandatory and valued system requirements
- Meeting New or Yet to be Defined Requirements
  – Robustness
    - Extensive use of proven COTS devices (e.g., timeliness of probe)
  – Flexibility/Scalability
    - In-vehicle equip., infrastructure, communication protocol, adjustments to fees/signage/traveler info.)
  – Safety
    - Preventing distracted driving by separating phone and PND
  – Security (Privacy)
    - Embedded safeguards (hardware/software/physical)
- Efficient Use of Mn/DOT's Resources
  – Our design can be implemented effectively and efficiently

Our System and Team Provide Exceptional Support to Achieve Critical Success Factors

1. **Understanding**
   - Mn/DOT objectives and stakeholder interests
   - Mn/DOT's ITS systems; National architecture; USDOT IntelliDrive program
   - Technical understanding of in-vehicle systems, software, infrastructure for IntelliDrive
2. **Robustness**
   - In-vehicle system, Communications Protocol, Infrastructure
3. **Flexibility/scalability**
   - Expansion to Minnesota, other States, U.S., Canada
   - Integration with future deployments, systems
4. **Protecting privacy** – tiered approach; software, hardware, physical
5. **Availability and adequacy of resources**
   - Experience matters !
   - Our system was designed to be implemented quickly and efficiently

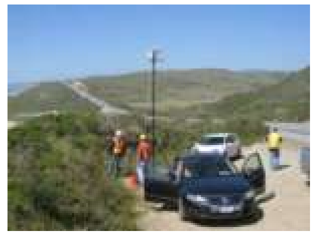
EXPERIENCE MATTERS

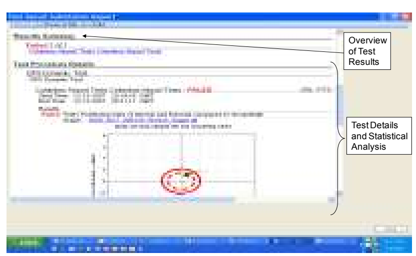
WE HAVE SUCCESSFULLY COMPLETED SIMILAR PROJECTS FOR U.S. DOT AND STATES

Experience Matters – Previous Vehicle System Design, Integration, Deployment

US DOT IntelliDrive^{SM} Proof of Concept

- Requirements and testing development
- Completed Raytheon's work when they were removed from the project by US DOT/VIIC
- Lead Systems Integrator
  - Hardware Integration
  - Software development, testing, and integration
- Recognized leaders in data management and analysis (Public and Private tests/analysis)

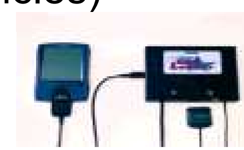


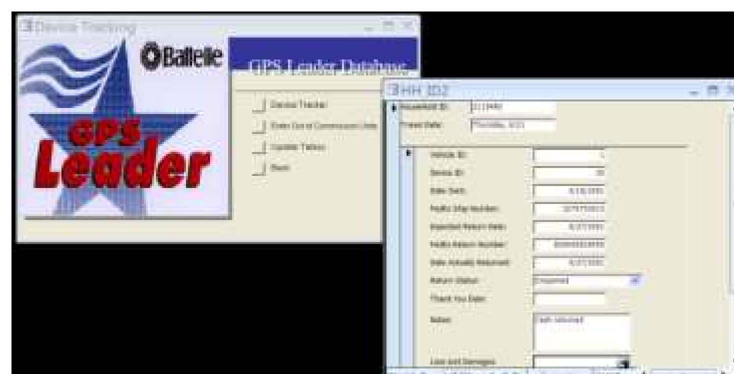


Field Deployment of GPS Devices to Capture Vehicle Movements (ODOT, SCAG)

- Battelle developed first ever GPS device to capture vehicle movements as part of household travel surveys
- GPS Leader device deployed in two HH surveys (> 1,500 vehicles)

Battelle's GPS Leader™





Extensive Experience Drove our Proposed Design

- We can visualize, design, and implement innovative cost-effective solutions for systems and software

Extensive Experience with Collection and Analysis of Probe Data Will Maximize Utility of the Data and Cost-Effectiveness/Benefits of the Project

- Impact to Efficiency
  - Eliminate inaccuracies in statistical tests of system performance by including ability to link probe data to vehicles (only during testing)
  - Appropriately allocate project resources in light of likely role of third-party vendors
    - Vendors of Probe data information (INRIX, Traffic.com)
    - Infrastructure operations and maintenance (no roadside equipment)
    - Third party payment alternative (PayPal)
- Impact to Utility of Probe Data
  - OBD-II data
  - Importance of probe data on **all** road segments regardless of location

Extensive Experience with Collection and Analysis of Probe Data Will Maximize Utility of the Data and Cost-Effectiveness/Benefits of the Project

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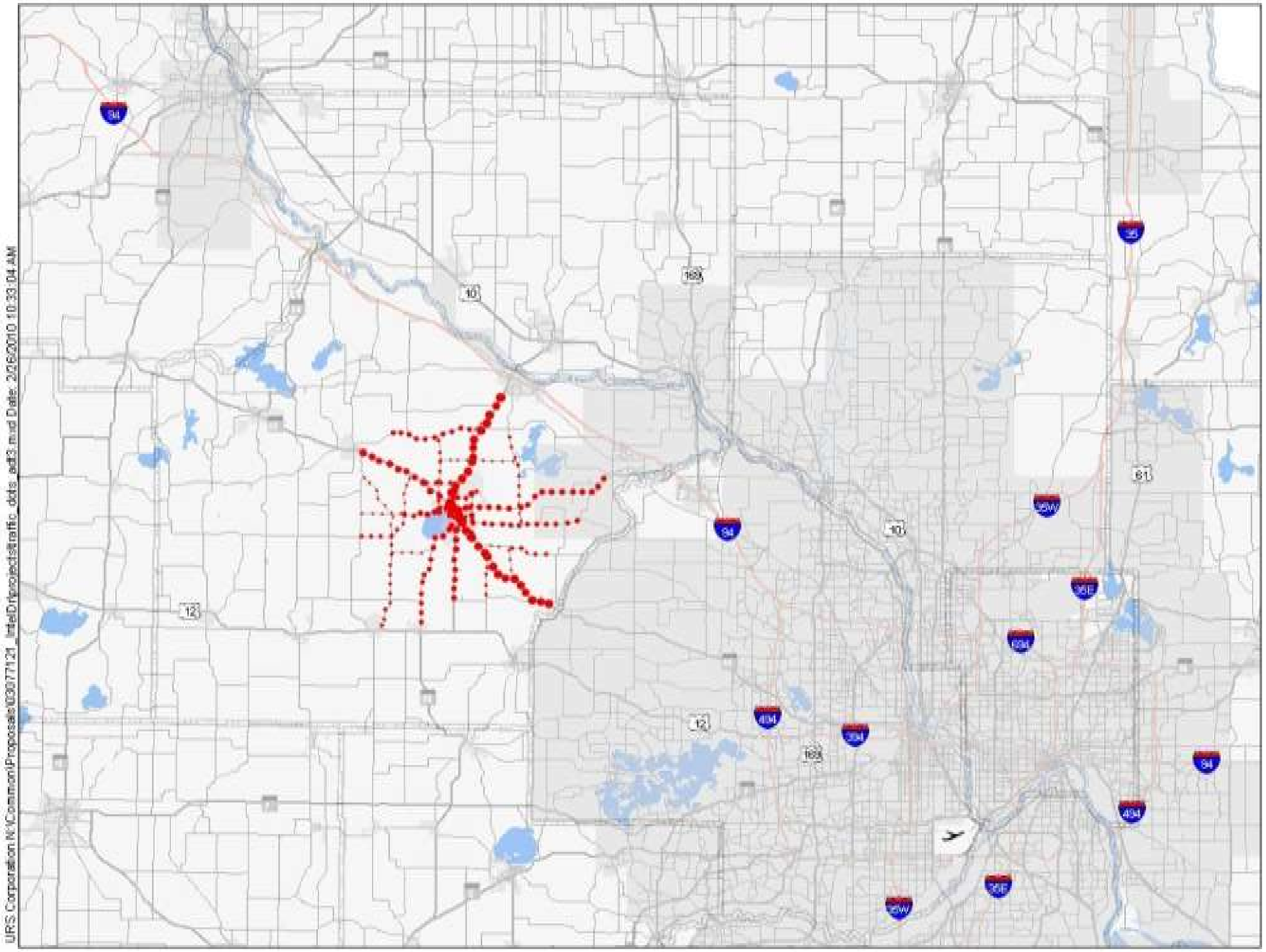
Importance of Comprehensive Probe Data



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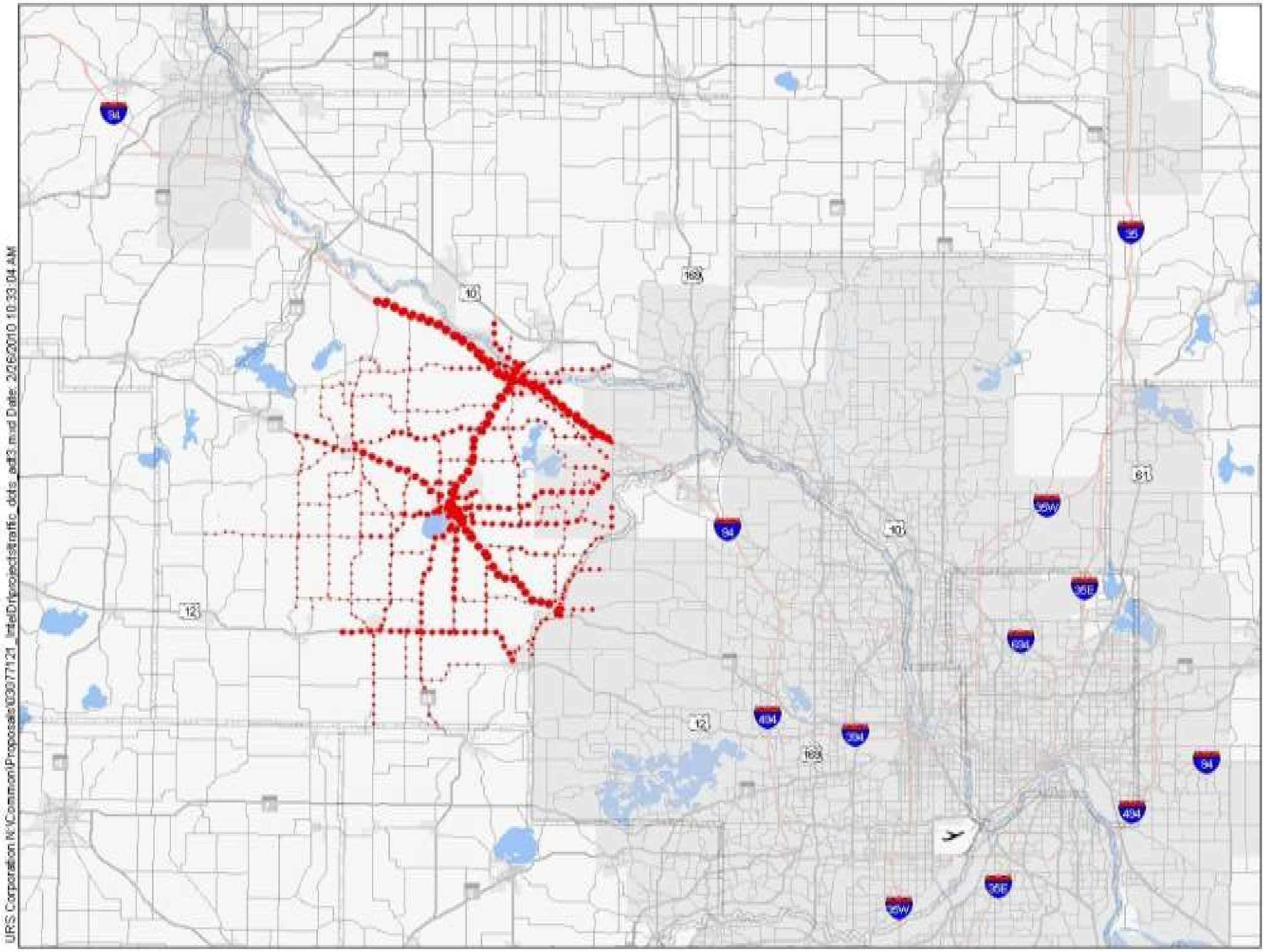

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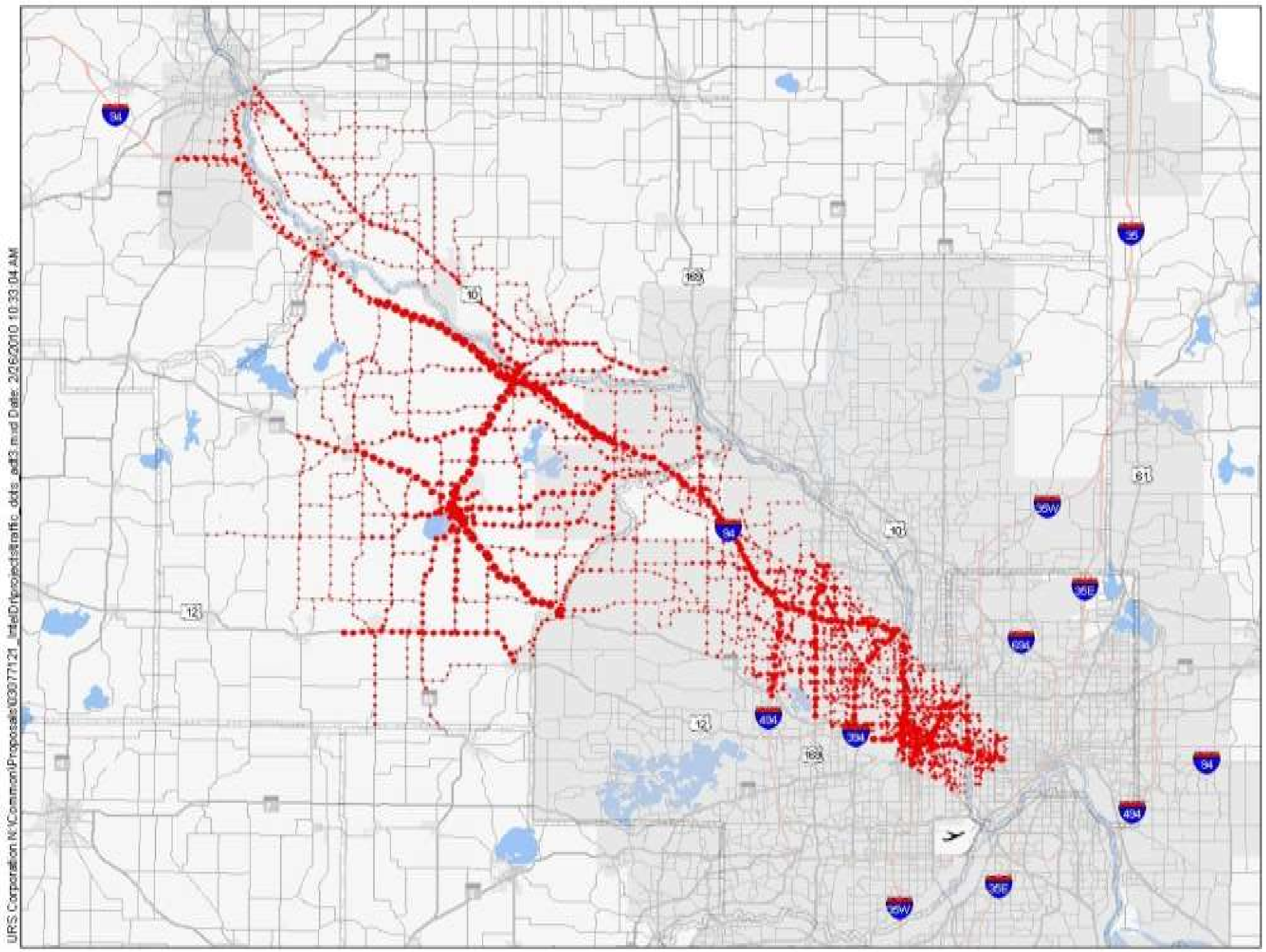

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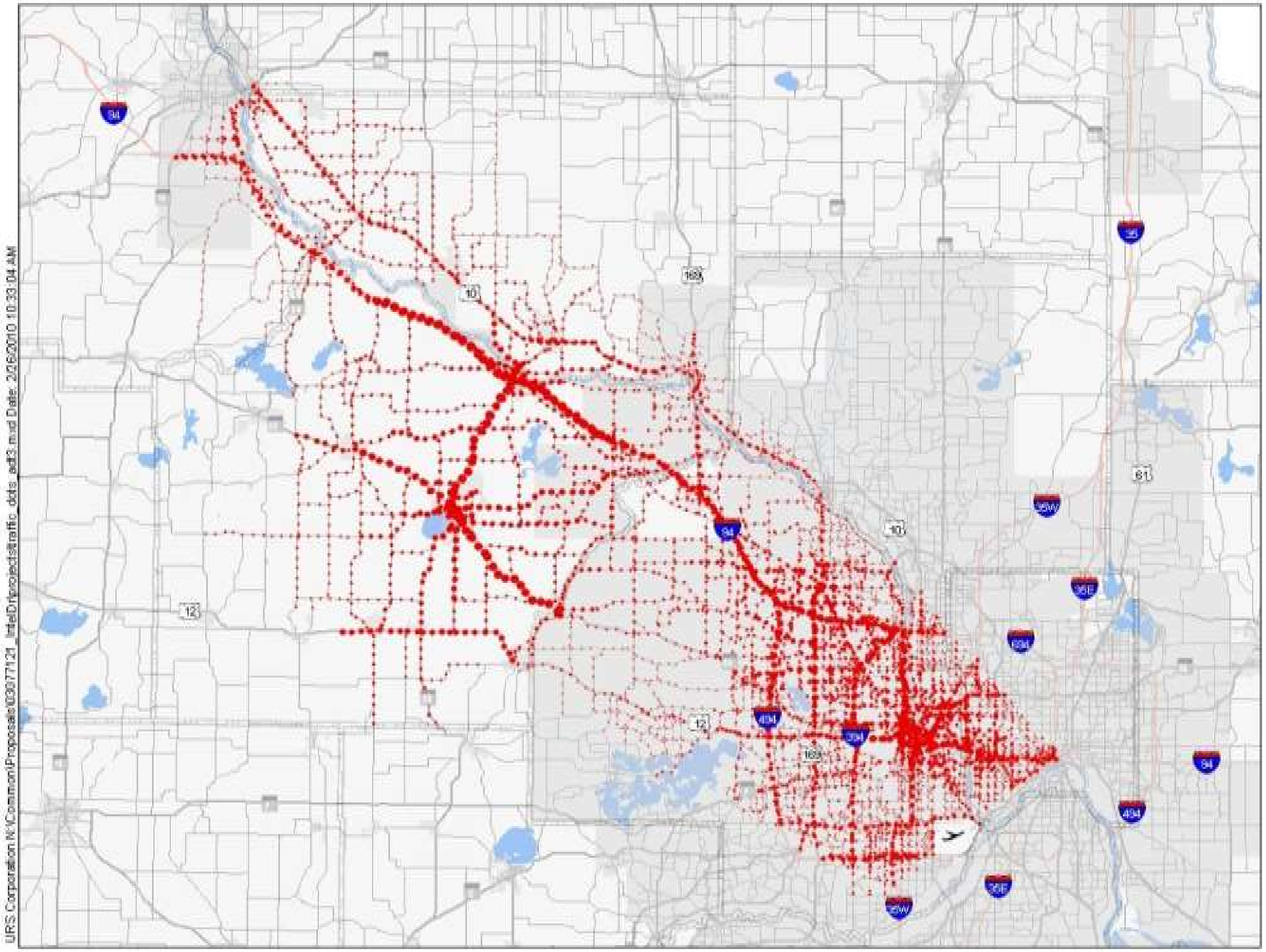

BUSINESS SENSITIVE

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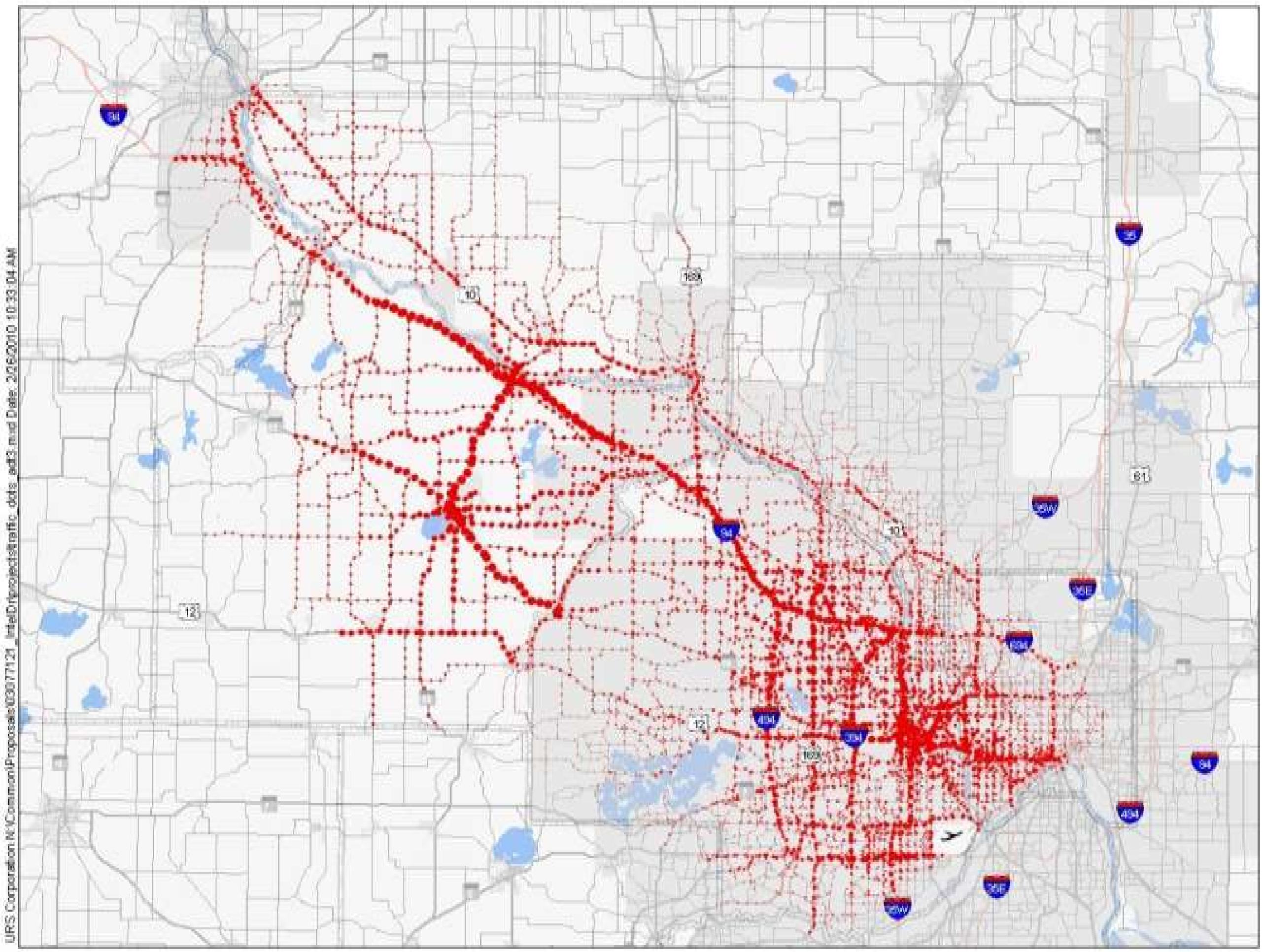


INFORMATION ON SPECIFIC INTERVIEW TOPICS

1. Establishing Pricing Zones/Fee Structure for MBUF:
Zone Establishment

- Our Approach
  - Allows for a comprehensive zone / fee structure and complete flexibility
- Our Goal
  - Prove concept / test robustness of system for a variety of scenarios
- Key Criteria Available with our System
  - Location – State, County, City, Township
  - Urban, Suburban, Rural
  - Roadway Facility
  - Time of Day, Day of Week
  - Direction of Travel
  - Volumes, ADT, V/C
  - Vehicle Type
  - Other (i.e. levels of congestion, construction, special events, commercial vehicle weight/number of axles, etc.)

1. Establishing Pricing Zones/Fee Structure for MBUF: Zone Establishment (cont.)

- Minimum project outcomes, zones & fee structure
  - Distinguish between Counties
  - Minnesota vs. Wisconsin
  - By roadway facility / classification
  - Rural vs. urban / suburban
  - Time of day, day of week
  - Direction of travel
  - ADT
  - Vehicle
- MBUF application integrates Battelle Team database and TomTom navigation software for
  - Comprehensive fee structure, or
  - Simple fee structure

1. Establishing Pricing Zones/Fee Structure for MBUF: Potential for Pricing Zones to Fit Nat'l IntelliDrive Program

- Potential to Fit into National IntelliDrive Program
  - Extremely flexible, fees for geography, specific roads, by state, etc.
  - Demonstrates both a "low tech" and a "high tech" solution
  - Manual odometer readings versus technology solution
- Potential to fit into Minnesota programs
  - Compatible with Transportation Operations / Traveler Info
    - RTMC / State TOCCs, MN 511
  - Compatible with U. of Minnesota's DSRC roadside equipment
  - Integrates with existing state/regional ITS architecture
  - Compliments existing user fee applications / existing policies
    - MnPASS program established public support
    - 3rd party handling of funds recommended
  - Revenue Flow – existing / future
    - Highway Tax Distribution Fund by Constitution

1. Establishing Pricing Zones/Fee Structure for MBUF: Process for Zone/Fee Structure Modification

- Pricing Zone/Fee Master Database
  - Maintained on application server
  - Can be updated by Mn/DOT via web-client
  - Base zones/fees included on devices prior to deployment
  - Zones can be defined as specific roads and/or geographic areas
  - Will “push” updates to vehicles at startup, at manual administration prompt (on-demand), or hourly
- On-board database
  - Include default fees
  - Includes identified specified zones
- Expandability
  - Too many zones at State/National level to hold all in on-board memory
  - Slightly modify software to create “region-level” geographical areas that would prompt download of new zones

2. Gathering Probe Data and Probe Data Transmission Probe Data Into Overall Architecture

- Probe data provides:
  - Ability to identify unusual traffic conditions – is another tool in incident detection & management toolbox
  - Can be used to identify bottlenecks (i.e., identify roadway design issues that need to be addressed)
- Comprehensive probe data regardless of location
  - Can be used to better inform travel demand models
  - Can eliminate or greatly reduce the need for large household travel surveys
  - Provides detailed information on AADT, throughput, and other metrics that are sparse for rural/local road segments

2. Gathering Probe Data and Probe Data Transmission
Specific Technologies Used in Probe Data Generation and Collection

- Probe data Generation
  - Map-corrected GPS information from TomTom Navigation Software
  - Calculated information (from position), heading, speed, acceleration
- Collection
  - Using AT&T Cellular 3G network
  - 3G/Edge (TCP/IP) provides built-in controls to confirm successful information transfer
    - At the time of data transmission, the In Vehicle software will know if a data communication failure occurred
  - SMS Messages
    - Probe data is fire and forget
    - MBUF data requires receipt acknowledgement
  - Store and re-transmit (MBUF)
    - Queue data for transmission when communications have been re-established
- Storage, Data management, and Analysis
  - Three server components: (a) Communications, (b) Application Processor, (c) Data warehouse

2. Gathering Probe Data and Probe Data Transmission
Using Probe Data with MBUF

- If vehicle identifier is included in probe data
  - Probe data can be used (post-analyzed) to validate MBUF data
  - Provides protection against data loss and auditable trace of mileage-based user fee charges
- We have proposed **NOT** to include vehicle identifier in probe data to protect privacy of participants
  - Will establish the ability to include identifier to support evaluation testing and audit sampling
- Vehicle position data used by on-board unit to accumulate miles by category
  - Miles by category only information submitted by on-board application to infrastructure components as an MBUF trip report
  - Post-processing of MBUF trip reports, submission date, timestamp to derive MBUF fees for each trip report, aggregation of these reports is total user fee

2. Gathering Probe Data and Probe Data Transmission
Using Probe Data with Enhanced Traveler Information

- Probe data could easily be used to compare actual versus historical traffic flow data
  - Not intending to use probe data to provide real-time alerts to participants
    - 500 vehicles represents small sample sizes – reliability/accuracy issues
    - Could be done if desired by Mn/DOT
  - Will develop analysis application and historical traffic flow database
    - Support algorithm development
    - Useful for larger deployment
  - We recognize independent vendors already (or will soon) provide this service either free or through subscription
    - INRIX, Traffic.com, etc.
    - Concept has already been proven in several tests
- Real-time traffic information will be provided through TomTom's Traffic Plus service

2. Gathering Probe Data and Probe Data Transmission
Preserving Privacy

- Software-Based Protections
  1. Vehicle identification **will not** be included in probe snapshot (except to support testing/audits)
  2. Probe data will be **encrypted** by in-vehicle device before transmission (RSA or AES encryption)
  3. Optional – post processing of probe data could be performed to **obfuscate origins/destinations**
- Hardware Protections
  3. **Secure backhaul** from AT&T's communications servers to Battelle's Communication Server
  4. Communication server **will not** decrypt message but will verify authenticity (sender SMS ID or IP address) and push only the encrypted message to the Application Server discarding the sender SMS ID or IP address
  5. All decryption performed **behind Battelle Corporate Firewall**
- Physical Protections
  6. Data maintained in **physically secure server hosting facility** on Battelle's campus, access controlled by security guard

3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions Speed of GPS Lock and Accuracy

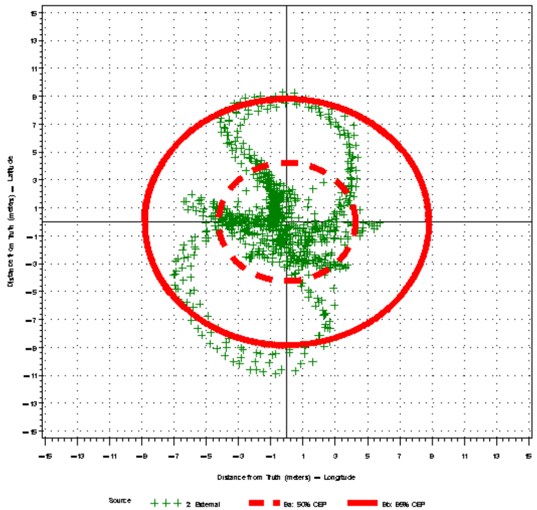
- Speed of GPS Lock
  - Dependent upon several factors (location, time of day, etc.)
  - TomTom Go 630 specifications (<30 seconds with free QuickFix^{TM})
    - Based upon 4 satellites
  - Wright County Test Results; average time to signal fix of 13 seconds
- GPS Accuracy
  - Function of speed, location (# of satellites), GPS chip, Kalman Filter implementation, augmentation, and map-matching
    - Can very significantly between devices even if same chipsets are used
  - TomTom Go 630 has SiRF Star III chipset
    - Horizontal Positional Accuracy: <2.5 m (but this is static!)
  - POC tests of SiRF indicate that
    - SiRF in dynamic environment has a mean of 3.6 meters, median 2.8, CEP of 8.8
  - Map-matching greatly improves accuracy
    - TomTom uses Tele Atlas map base

3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions
Speed of GPS Lock and Accuracy (cont.)

Dynamic Accuracy
Mean Distance From Truth
3.6 Meters

Median Distance from Truth
2.8 Meters

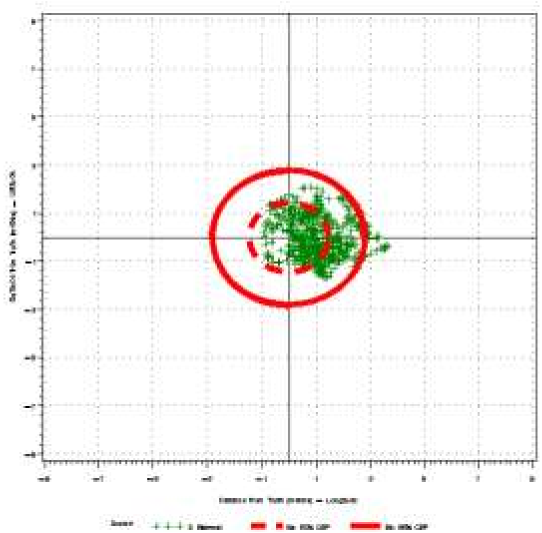
95% Circular Error Probability
8.8 meters



Static Accuracy
Mean Distance From Truth
1.5 Meters

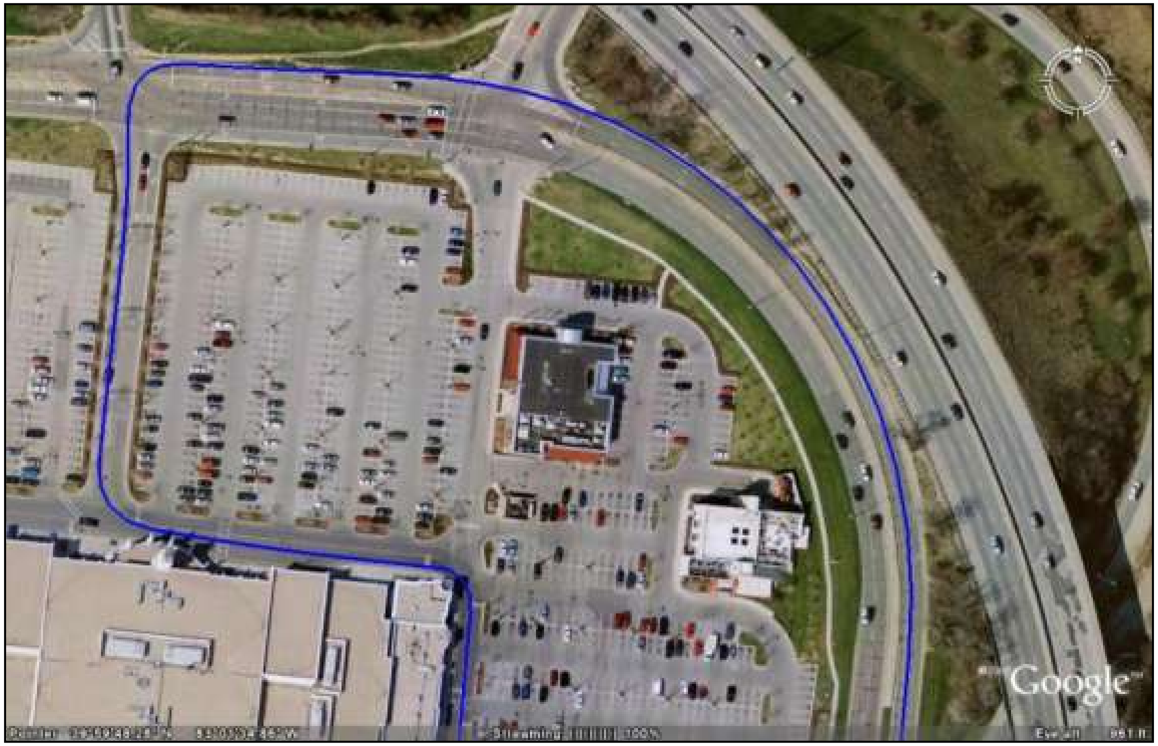
Median Distance from Truth
0.7 Meters

95% Circular Error Probability
2.8 meters



3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions Speed of GPS Lock and Accuracy (cont.)

- Map-Matched GPS from Personal Navigation Devices is "good enough" for MBUF, Probe, Signage
  - Ability to identify different road categories
  - Ability to calculate mileage, speed, position frequently



Map-Matching

- Snaps GPS to Road
- Only as good as base-map - Tele Atlas one of the best in the world
- Ford Test Results demonstrated significant gain in accuracy

3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions
Potential Strengths/Weaknesses

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Cellular Network

Strengths

- Near universal coverage area
- Well established 3rd party service cellular providers/infrastructure
- Household coverage already has extensive penetration, will only increase
- Supports rapid deployment schedule
- Eliminates need for extensive infrastructure investments by Mn/DOT
- "High" and "Low" data transfer bandwidths available
- Multiple service providers

Weaknesses

- Subject to same limitations as Wi-Fi – potential for data bandwidth issues during peak times
  - Loss of data connection
  - Delay in data transfer
- Would require participants (future) to have wireless accounts with data or SMS capability
- Will be too expensive for certain segments of population
- Can be easily disabled by subject participants (as opposed to RFID tags)

3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions Potential Strengths/Weaknesses

Personal Navigation Devices for GPS

Strengths

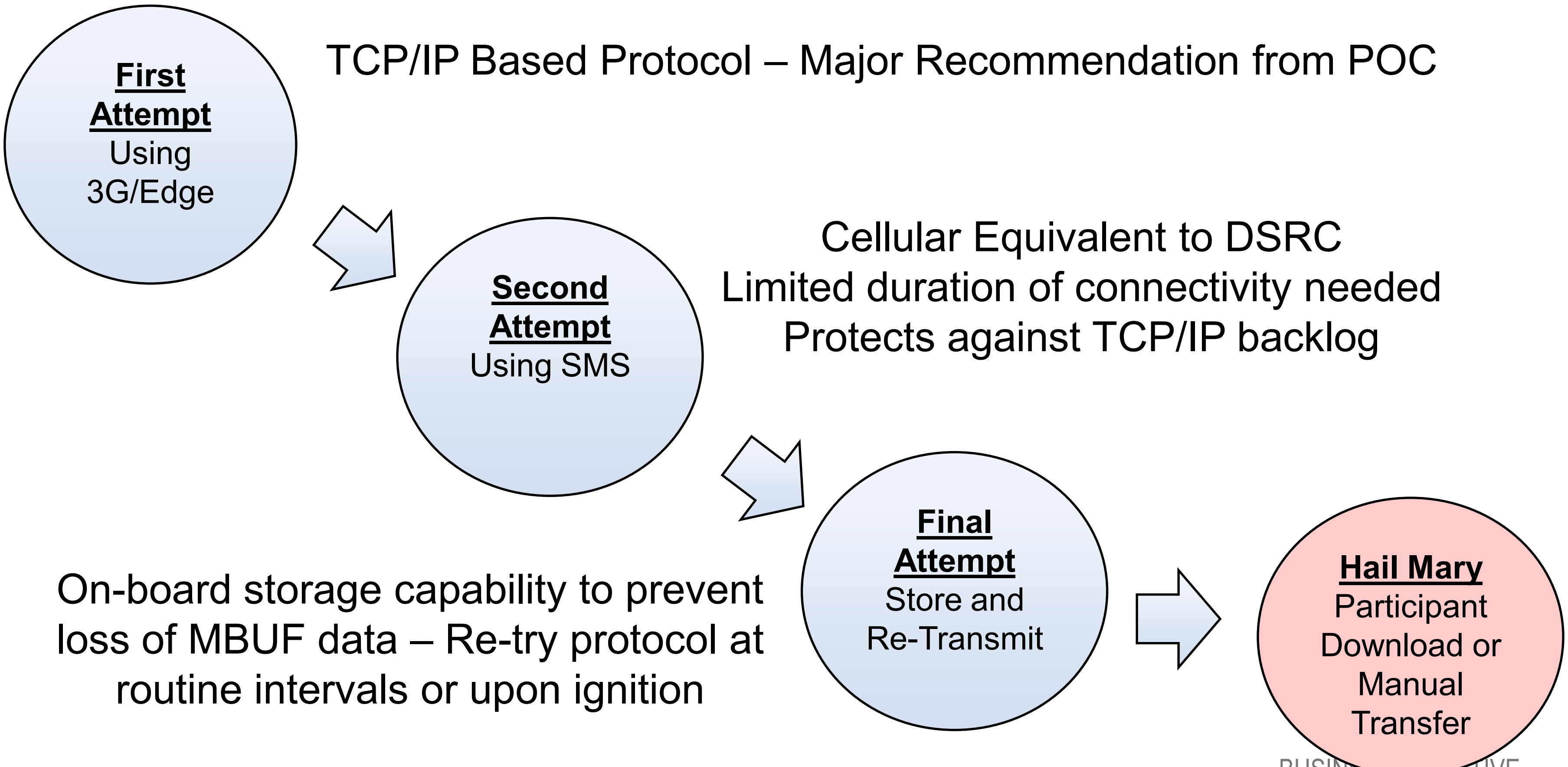
- Extensive market penetration
- Easy to use by participants
- Promotes utilization by providing navigation benefit
- Processor “strong enough” to support applications
  - 1.X Ghz, 1-3 GB storage
- Accuracy “good-enough” for these applications
- Established vendors technology proven
- Relatively low cost compared to other OBE or OBE/RSE combinations

Weaknesses

- Processors limited compared to more expensive OBE
  - Can be enhanced by utilizing both phone and TomTom for processing
  - Can be enhanced with external memory
- Will not be available to everyone
  - Segments of population will be too expensive
- May not support safety applications (processor lag) at intersections

3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions
Mitigating Risk for Potential Communication Failures

- Proposing a tiered communication protocol
- Eliminates need for alternatives to cellular



3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions

Alternative Options for Cellular Network Connections

- Additional options beyond those proposed (TCP/IP, SMS, DSRC for Intersections) are not needed but could be incorporated under our system design
- Other Alternatives Considered
  - Satellite Communications (OnStar, QUALCOMM)
    - Not widespread use, proprietary systems
  - RFID, Transponders, DSRC
    - Used extensively in Europe for tracking vehicle movements/fees
    - Commonly used in US tolling facilities
    - Requires extensive roadside infrastructure (readers)
    - Only can capture data where infrastructure exists
  - Wi-Fi
    - Possible in Minneapolis because of large Wi-Fi coverage, but Wright county not covered
    - Not as common in other areas – limits probe data collection
    - Significant "handshake" needed for communications
    - Possible backup to cellular coverage – especially as personal wi-fi networks gain in popularity
      - Register your car with your home network – **potentially a good option for MBUF**

3. Use/Robustness of Cellular Phones and In-Vehicle Navigation Units for GPS Functions
Power Consumption and Effects on Vehicle Battery

- Battelle Team's Design has negligible impact on vehicle battery due to incorporation of APO3 unit

Automatic Power Off 3 (APO3)

- Designed for 12 volt vehicle electrical systems with negative ground.
- Shutdown voltage can be set to one of four pre-programmed voltages (11.8, 12.1, 12.7, 13.05 volts)
- Shutdown delay can be set to one of four pre-programmed times (0, 5, 10, 20 minutes)

- Requirements When Vehicle On
  - Less than 500mA, based on:
    - TomTom GO 630: ~265mA (1320mAH/5hrs)
    - Erricsson W810 Phone: ~110mA (900mAH/8hrs)
    - APO3 Smart Switch: ~60mA
- Requirements When Vehicle Power Off
  - Less than 2mA
  - System could sit in idle car for 3 months with no impact

4. Ability to be Leveraged into State-Wide, Nation-Wide, North American-Wide Deployment Modularity of System Components

- **Battelle Team's Proposed System Will:**
  - Work with virtually any cellular phone Bluetooth compatible with TomTom
  - Work with both "low-end" and "high-end" PNDs (incl. "All-in-ones")
  - Work with all cellular providers
  - Not require DOT's to create vast network of roadside infrastructure components
  - Allow users to utilize "older" PNDs while maximizing benefits of new cellular technology
- **Portability to other systems**
  - Simply requires software development for other OS
    - Droid, iPhone, Palm, Garmin
- **Incorporation of additional communication protocols**
  - Just requires updating the Communications Service Layer on the in-vehicle device; can be customized for each device
  - Easy to add additional communication options as they become available (i.e., wi-fi, wi-max, etc.)

4. Ability to be Leveraged into State-Wide, Nation-Wide, North American-Wide Deployment Transferability of System Between States

- The Battelle Team's Proposed System is easily transferred to other States/National/North America
  - Nothing "Minnesota" specific hard designed into the system
    - No roadside equipment needed
    - No specialized in-vehicle transponders/RFID equipment needed
  - User fees can be assigned by geographical area, but customized to specific road segments within a State, geographical area
  - Design includes ability to update on-board database
    - Does not require on-board unit to have entire State, US, or N. America stored on-board
    - Fees, signage displays can be made geographic specific (i.e., like a State)
  - Will work with any cellular provider
    - Limited only by cellular coverage

4. Ability to be Leveraged into State-Wide, Nation-Wide, North American-Wide Deployment Scalability of System Components

- In-Vehicle System
  - Easily modifiable to other devices/Operating Systems
  - Facilitates software updates for emerging technology
- Infrastructure Components
  - Standard server design
  - Expected to have multiple servers within each State
    - Can be centralized for maintenance and management
  - Additional States could have separate servers
    - Linked by Internet, automatic transfer of data between states
  - Infrastructure software/hardware based upon commercial applications – not proprietary database system or OS
    - SQL Server, Oracle, C++

4. Ability to be Leveraged into State-Wide, Nation-Wide, North American-Wide Deployment Coordination with State Agencies/Legislation

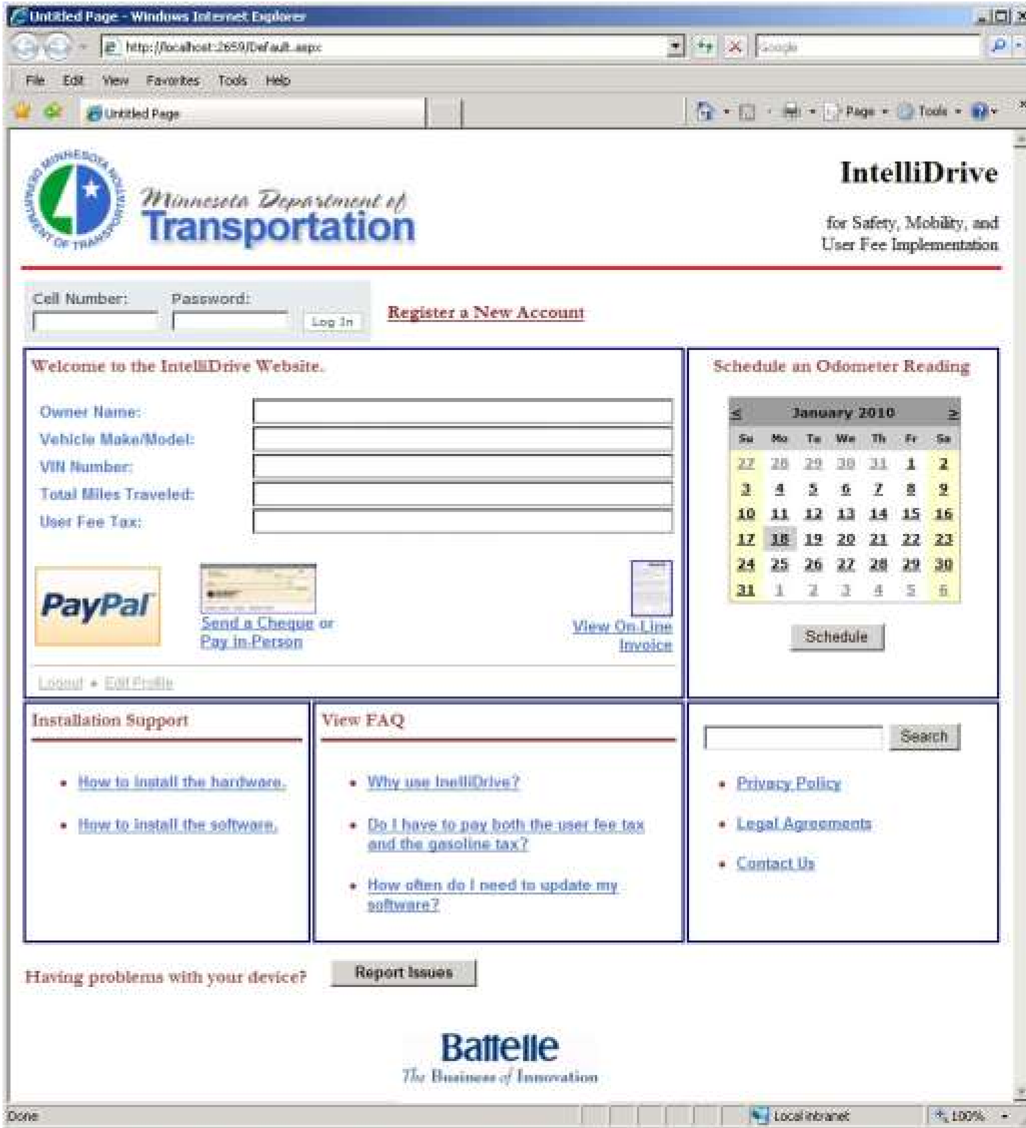
- Minnesota
  - Need legislation to create statutory authority to collect and allocate MBUF fees
  - Need approval of administrative processes and administrating agency
  - Would need to increase enforcement integration across agencies
- State to State, Country to Country
  - System could be implemented State-by-State
  - Does not require centralized “national” infrastructure or program to be implemented
  - Battelle Team approach facilitates open architecture, multiple COTS products and cost effective solution

4. Ability to be Leveraged into State-Wide, Nation-Wide, North American-Wide Deployment
Privacy Options

- Privacy – Layered Approach (Hardware, Software, Physical)
  - Encryption
  - Avoid transfer of detailed location and vehicle identifier
  - Data protection protocols (firewall, physical security)
- Option to participate without GPS using flat fee and miles driven
- Utilize state income tax rebates during technology / revenue flow transition
- Data privacy practice laws may need to be addressed

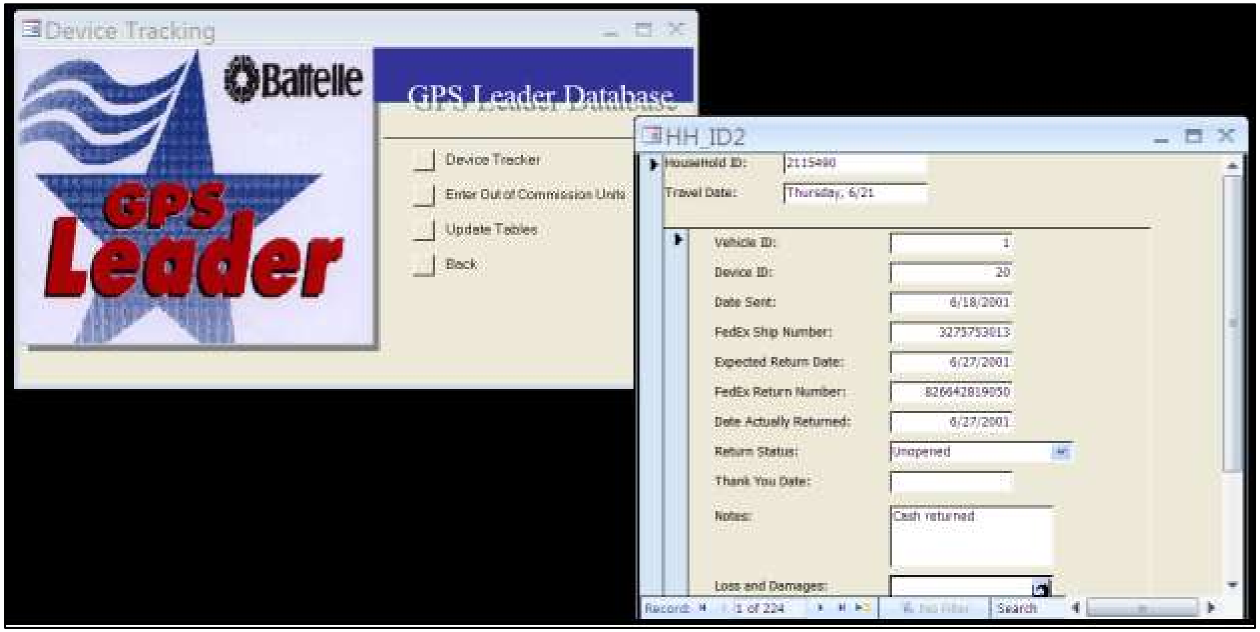
5. Method of Collecting Mileage Based User Fees
Establishing User Accounts/Recruitment

- User Accounts
  - Establish "PayPal" accounts for each participant – link to license plate, VIN
  - Establish user accounts for Participant Portal and Web-Client



5. Method of Collecting Mileage Based User Fees Recruitment/Distribution of Equipment

- Battelle Team Will Support Recruitment and Equipment Deployment
  - Modify our existing recruitment and equipment tracking system
  - Confirm participation/address prior to shipment (via telephone)
  - Ship units via FedEx with Return FedEx pre-paid label



5. Method of Collecting Mileage Based User Fees Enforcement

- Provide staged participant incentives
- Notifications on in-vehicle device
- Email / letter / phone follow-up as needed
- DPS Driver and Vehicle Services Division
  - Get access to payment status of participants via system input/output interface
  - Option - link to license tag renewals
- Before/After odometer reading inspections
  - Capture data to assess completeness of equipment gathered MBUF data
  - Used to identify miles not captured by equipment

5. Method of Collecting Mileage Based User Fees Customer Service Options

- In-Person Support by:
  - Local offices in Wright County, Minneapolis
  - Dedicated parking at offices
  - Installation support as well as troubleshooting & odometer readings
- Telephone “hot-line”
- Participant Portal
  - E-mail support
  - FAQs and Answers
  - Installation video/instructions

5. Method of Collecting Mileage Based User Fees Billing Structure Flexibility

- Electronic Payments via Participant Portal
  - PayPal account
  - Credit cards
  - Debit cards
- Money Orders or Check mailed to Customer Service Center
  - Cash or check paid in-person at Customer Service Center
- Monthly invoices, customer preferred cycle, on-demand
  - Email or hard copy
  - Participants could pay electronic invoices any time
  - Participants will be able to generate an invoice on-demand

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5. Method of Collecting Mileage Based User Fees
Mileage Based User Fee Preserving Privacy

- Mileage Based User Fees for each trip not calculated on-board unit
  - In-vehicle unit displays fee for each road segment
  - Only summarizes mileage driven by road segment
- Only aggregation of miles by roadway category (not GPS coordinates) submitted
  - Vehicle Identifier
  - Miles by fee category
  - **Complete separation of Probe data and MBUF data**
- User fee assessments performed behind corporate firewall (infrastructure application)
- Invoices presented to participant via secure account login

6. Resources Necessary and Sufficient Proposed Labor Hours by Task and Firm

- Experience Facilitates Efficiency
  - Leverage existing software, hardware, staff
    - Recruitment and equipment tracking tool
    - Web-client for database/system interaction
    - Probe data analysis tools
    - IntelliDrive POC software applications (including custom software)
  - Provides a realistic basis for cost estimation
    - Past projects include software development and systems integration as well as deployment of GPS devices into vehicles
    - Understanding of effort required to integrate COTS
- Costs developed through PMI standard protocols
  - Detailed Work Breakdown Structure, Time-Phased Budget

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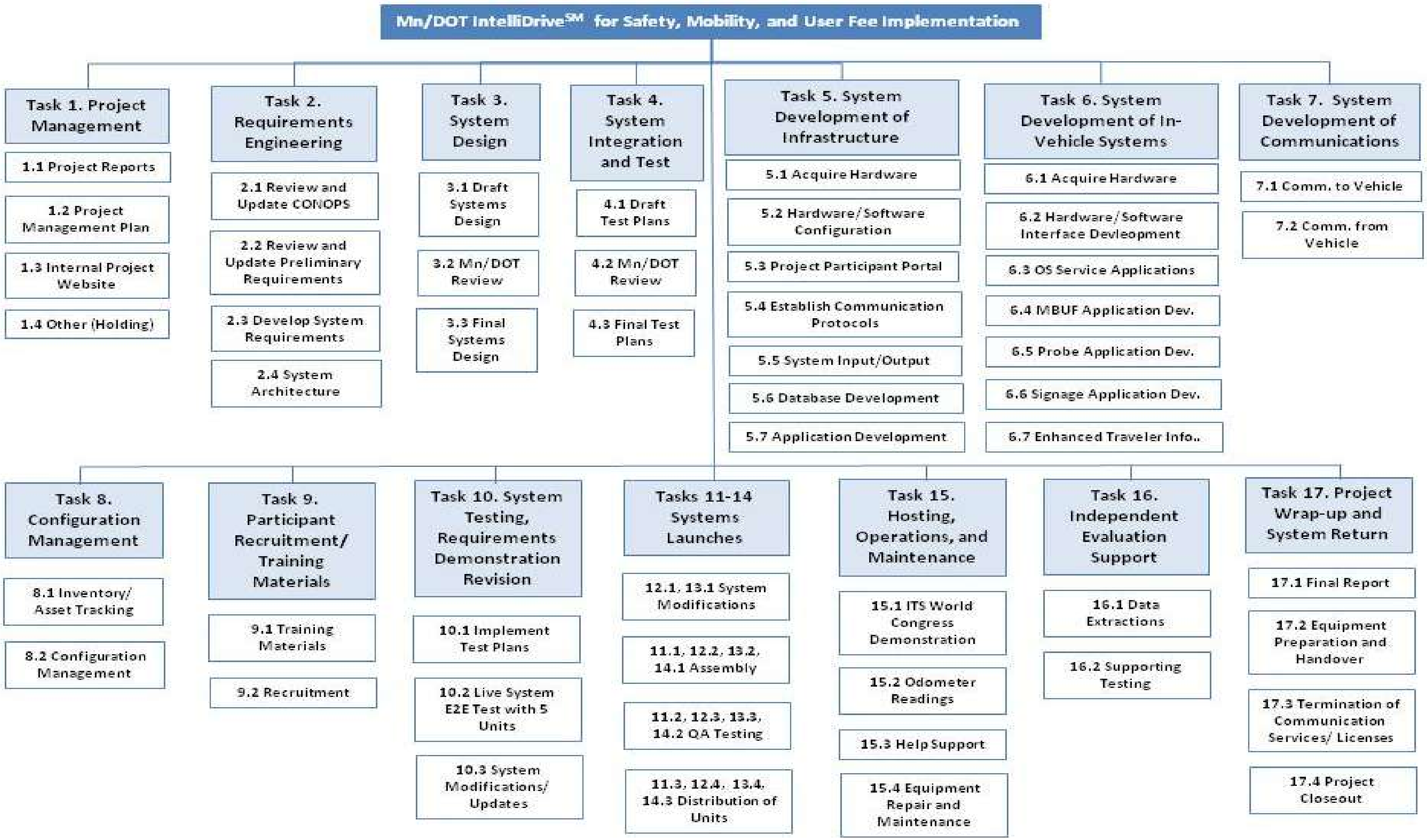
6. Resources Necessary and Sufficient Work Breakdown Structure



6. Resources Necessary and Sufficient Proposed Labor Hours by Task and Firm

Task	Battelle	URS	Pierce Pini	Symbiont
1. Project Management	1,098	728	-	-
2. Requirements Engineering	500	476	-	-
3. System Design	340	256	-	-
4. System Integration and Test Plan	210	488	-	-
5. System Dev. of Supporting Infrastructure	3,546	136	-	100
6. System Development of In-Vehicle Systems	2,950	80	-	100
7. System Development of Communications	330	136	-	-
8. Configuration Management	180	224	-	-
9. Participant Recruitment and Training Materials	240	-	-	-
10. System Testing, Reqmts. Demo., Revisions	625	876	60	-
11. Initial Systems Launch	908	116	160	50
12. Second Systems Launch	740	100	150	50
13. Third Systems Launch	775	100	160	50
14. Final System Launch	507	100	80	50
15. Hosting, Operations and Maintenance	3,058	248	480	100
16. Independent Evaluation Support	610	92	-	-
17. Project Wrap-up and System Return	685	476	-	-
Total	**17,302**	**4,632**	**1,090**	**500**

6. Resources Necessary and Sufficient Time Phased Budget

Work Breakdown Structure Element/Task	Anticipated Start Date	Proposed Completion Date	Percent of Effort	Hours	FTEs Needed	Labor Costs
1. Project Management	**3/1/2010**	**9/6/2012**	**100%**	**1826**		**$ 261,093**
1.1 Monthly/Quarterly Project Reports	3/1/2010	9/6/2012	15%	274	0.05	$ 39,164
1.2 Project Management Plan Development and Updating	3/1/2010	9/6/2012	50%	913	0.17	$ 130,547
1.3 Internal Project Website	3/1/2010	3/11/2010	5%	91	1.58	$ 13,055
1.4 Other PM Activities	3/1/2010	9/6/2012	30%	548	0.10	$ 78,328
2. Requirements Engineering	**3/1/2010**	**5/15/2010**	**100%**	**976**		**$ 139,179**
2.1 Review and Update Concept of Operations	3/1/2010	3/21/2010	25%	244	2.12	$ 34,795
2.2 Review and Update Preliminary Requirements	3/21/2010	4/20/2010	10%	98	0.56	$ 13,918
2.3 Develop Systems Requirements	3/21/2010	5/5/2010	50%	488	1.88	$ 69,589
2.4 System Architecture	5/5/2010	5/15/2010	15%	146	2.54	$ 20,877
3. System Design	**3/1/2010**	**4/26/2010**	**100%**	**596**		**$ 85,140**
3.1 Draft Systems Design	3/1/2010	3/29/2010	75%	447	2.77	$ 63,855
3.2 Mn/DOT Review of Draft Systems Design	3/29/2010	4/12/2010	0%	0	0.00	$ -
3.3 Final Systems Design	4/12/2010	4/26/2010	25%	149	1.85	$ 21,285
4. System Integration and Test Plan	**3/29/2010**	**6/7/2010**	**100%**	**698**		**$ 98,896**
4.1 Draft Test Plans	3/29/2010	4/26/2010	75%	524	3.24	$ 74,172
4.2 Mn/DOT Review of Draft Test Plans	4/26/2010	5/10/2010	0%	0	0.00	$ -
4.3 Final Test Plans	5/10/2010	6/7/2010	25%	175	1.08	$ 24,724
5. System Development of Supporting Infrastructure	**3/1/2010**	**8/14/2010**	**100%**	**3782**		**$ 536,442**
5.1 Acquire Infrastructure Hardware/Software	4/26/2010	5/26/2010	1%	38	0.22	$ 5,364
5.2 Hardware/Software Configuration	5/26/2010	6/5/2010	10%	378	6.56	$ 53,644
5.3 Project Participant Portal Website Development	3/1/2010	3/11/2010	1%	38	0.66	$ 5,364
5.4 Establish Communications Protocols Between Components	5/26/2010	6/5/2010	5%	189	3.28	$ 26,822
5.5 System Input/Output Interface Development	4/26/2010	6/25/2010	5%	189	0.55	$ 26,822
5.6 Database Development	5/26/2010	6/25/2010	25%	946	5.47	$ 134,110
5.7 Analysis Processing and Reporting Application Development	6/10/2010	8/14/2010	53%	2004	5.35	$ 284,314
6. System Development of In-Vehicle Systems	**4/26/2010**	**9/3/2010**	**100%**	**3130**		**$ 442,331**
6.1 Acquire In-Vehicle Hardware/Software	4/26/2010	5/26/2010	1%	31	0.18	$ 4,423
6.2 Hardware/Software Interface Development	5/26/2010	6/15/2010	5%	157	1.36	$ 22,117
6.3 Operating System Service Applications (Position, Comm.)	5/26/2010	6/25/2010	25%	783	4.52	$ 110,583
6.4 MBUF Application Development	6/25/2010	8/24/2010	24%	751	2.17	$ 106,160
6.5 Probe Data Application Development	6/25/2010	8/24/2010	20%	626	1.81	$ 88,466
6.6 In-Vehicle Signage Application Development	6/25/2010	8/24/2010	20%	626	1.81	$ 88,466
6.7 Enhanced Traveler Information - Integration with Signage	8/24/2010	9/3/2010	5%	157	2.71	$ 22,117

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6. Resources Necessary and Sufficient Time Phased Budget (cont.)

Work Breakdown Structure Element/Task	Anticipated Start Date	Proposed Completion Date	Percent of Effort	Hours	FTEs Needed	Labor Costs
7. System Development of Communications	**6/15/2010**	**6/25/2010**	**100%**	**466**		**$ 66,847**
7.1 Communication to In-Vehicle Equipment	6/15/2010	6/25/2010	50%	233	4.04	$ 33,424
7.2 Communication from In-Vehicle Equipment	6/15/2010	6/25/2010	50%	233	4.04	$ 33,424
8. Configuration Management	**5/26/2010**	**9/2/2012**	**100%**	**404**		**$ 57,494**
8.1 Inventory/Asset Tracking	5/26/2010	9/2/2012	60%	242	0.05	$ 34,496
8.2 Configuration Management	5/26/2010	9/2/2012	40%	162	0.03	$ 22,998
9. Participant Recruitment and Training Materials	**9/3/2010**	**6/10/2011**	**100%**	**240**		**$ 34,731**
9.1 Training Materials	9/3/2010	9/7/2010	20%	48	2.08	$ 6,946
9.2 Participation in Recruitment Process	9/3/2010	6/10/2011	80%	192	0.12	$ 27,785
10. System Testing, Requirements Demonstration, Revisions	**9/3/2010**	**10/8/2010**	**100%**	**1561**		**$ 220,321**
10.1 Implement Test Plans	9/3/2010	9/23/2010	50%	781	6.77	$ 110,161
10.2 Five System Test E2E with Participants	9/23/2010	9/28/2010	25%	390	13.53	$ 55,080
10.3 System Modifications/Updates	9/28/2010	10/8/2010	25%	390	6.77	$ 55,080
11. Initial Systems Launch	**10/8/2010**	**10/31/2010**	**100%**	**1234**		**$ 168,183**
11.1 Assembly	10/8/2010	10/23/2010	40%	494	5.71	$ 67,273
11.2 QA Testing of Units	10/8/2010	10/28/2010	40%	494	4.28	$ 67,273
11.3 Distribution of Units	10/28/2010	10/31/2010	20%	247	14.27	$ 33,637
12. Second Systems Launch	**10/31/2010**	**1/7/2011**	**100%**	**1040**		**$ 140,475**
12.1 System Modifications	10/31/2010	11/30/2010	10%	104	0.60	$ 14,048
12.2 Assembly	11/30/2010	12/15/2010	30%	312	3.61	$ 42,143
12.3 QA Testing of Units	12/15/2010	1/4/2011	40%	416	3.61	$ 56,190
12.4 Distribution of Units	1/4/2011	1/7/2011	20%	208	12.02	$ 28,095
13. Third Systems Launch	**1/7/2011**	**4/5/2011**	**100%**	**1085**		**$ 146,690**
13.1 System Modifications	1/7/2011	2/21/2011	10%	109	0.42	$ 14,669
13.2 Assembly	2/21/2011	3/13/2011	30%	326	2.82	$ 44,007
13.3 QA Testing of Units	3/13/2011	4/2/2011	40%	434	3.76	$ 58,676
13.4 Distribution of Units	4/2/2011	4/5/2011	20%	217	12.54	$ 29,338
14. Final System Launch	**4/5/2011**	**7/7/2011**	**100%**	**737**		**$ 98,707**
14.1 Assembly	4/5/2011	6/14/2011	40%	295	0.73	$ 39,483
14.2 QA Testing of Units	6/14/2011	7/4/2011	40%	295	2.56	$ 39,483
14.3 Distribution of Units	7/4/2011	7/7/2011	20%	147	8.52	$ 19,741

6. Resources Necessary and Sufficient Time Phased Budget (cont.)

Work Breakdown Structure Element/Task	Anticipated Start Date	Proposed Completion Date	Percent of Effort	Hours	FTEs Needed	Labor Costs
15. Hosting, Operations and Maintenance	**6/10/2011**	**8/3/2012**	**100%**	**3886**		**$ 536,747**
15.1 Technology Demonstration for 18th Annual ITS World Congress	9/1/2011	10/31/2011	20%	777	2.25	$ 107,349
15.2 Odometer Readings	6/10/2011	8/3/2012	40%	1554	0.64	$ 214,699
15.3 Help Support	6/10/2011	8/3/2012	35%	1360	0.56	$ 187,861
15.4 Equipment Repair and Maintenance	6/10/2011	4/5/2012	5%	194	0.11	$ 26,837
16. Independent Evaluation Support	**1/3/2011**	**6/16/2012**	**100%**	**702**		**$ 101,190**
16.1 Data Extractions	1/3/2011	6/16/2012	30%	211	0.07	$ 30,357
16.2 Supporting Testing	1/3/2011	6/16/2012	70%	491	0.16	$ 70,833
17. Project Wrap-up and System Return	**8/3/2012**	**9/2/2012**	**100%**	**1161**		**$ 165,951**
17.1 Final Report	8/3/2012	9/2/2012	50%	581	3.36	$ 82,975
17.2 Equipment Preparation and Handover	8/3/2012	9/2/2012	30%	348	2.01	$ 49,785
17.3 Termination of Communication Services/Licenses	8/3/2012	8/8/2012	5%	58	2.01	$ 8,298
17.4 Project Closeout	8/3/2012	8/23/2012	15%	174	1.51	$ 24,893

6. Resources Necessary and Sufficient Staffing by Category

- Critical Resources
  - System Design/Architecture
    - Seven Staff available to various extents
  - Software Development
    - Core team of 6 software developers
      - Matt Burns – Lead Software Engineer
      - Programmer 1 – Communications Service
      - Programmer 2 – Positioning Service
      - Programmer 3 – MBUF Application
      - Programmer 4 – Probe Application
      - Programmer 5 – In-vehicle Signage and Enhanced Traveler Info.
      - Programmer 6 – Infrastructure database, web-client, participant portal
      - Ben Pierce – Infrastructure summaries and analysis

6. Resources Necessary and Sufficient Equipment

Item	Rough Costs
Computer Tapes (Backup)	1,000
Wireless Service	318,000
AT&T Secure Backhaul	3,000
TomTom GO 630	$102,000
Automatic Power Off (APO3), OEM radio connector	$31,000
RoadPro 12 Volt 12' Cigarette Lighter Extension Corf	$15,000
Friction Fit Plastic Craft Box and Lid - Item #16	$500
TomTom's Traffic Plus	$59,000
Communications Server	$4,000
Applications Server	$6,000
Data Warehouse Server	$14,000
MobiWAVE- Wireless vehicular on-board unit	$18,000
PayPal Fees for E-Payments	$3,000
USPS Shipping Fees for Large Flat Rate Boxes	$16,000
Sony Ericsson W810i	$132,000

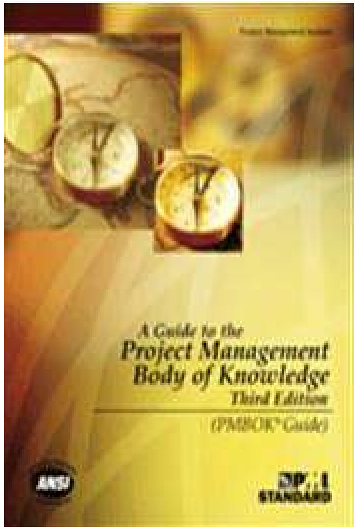
6. Resources Necessary and Sufficient Comparison of Proposed Labor Hours to Previous Projects

Projects	Mn/DOT IntelliDrive for Mobility, Safety, and User Fees	Comparison Project		
		VII Proof-of-Concept	Ohio Department of Transportation GPS Travel Survey*	Southern California Association of Governments GPS Travel Survey*
Scope of Work	• Requirements specifications • System Design • Software development • Field deployment of 500 devices • Operations and Maintenance of infrastructure servers	• Requirements specifications • System Integration • Software testing and development of test and analysis tools • Field deployment of 20 vehicles • Test and Evaluation	• Participant recruitment support • Preparation of field materials • Deployment of GPS devices in 383 households (740 vehicles) • Post processing and analysis of GPS data	• Participant recruitment support • Preparation of field materials • Deployment of GPS devices in 820 households (1,217 vehicles) • Post processing and analysis of GPS data
Period of Performance	2.25 years	3 years	2 years (bulk completed in 8 months)	8 months
Total Labor Hours	23,524	31,756	1,691	3,086

* No software or equipment development included

7. Project Management Approach

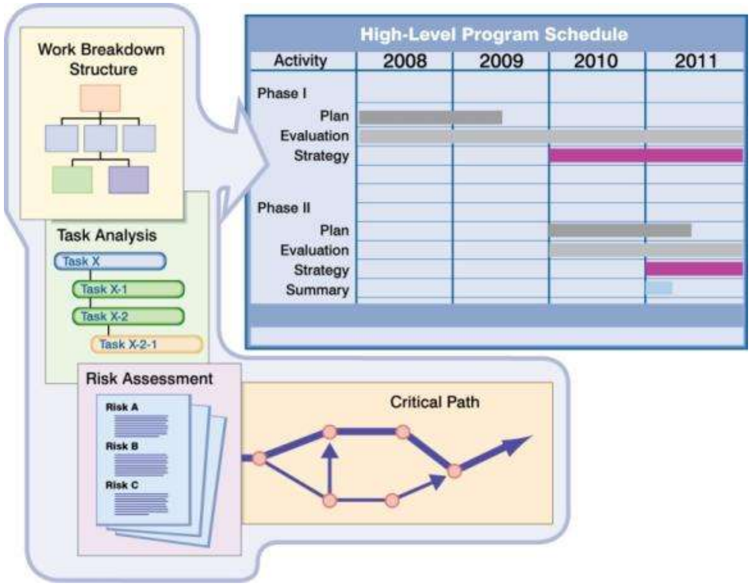
- Utilization of best practice standards, such as those promoted by PMI and ISO
  - Project Management Plan (PMP)
  - Earned value management for schedule/cost control
  - Integrated change control
  - ISO 9001 SOPs for quality management



7. Project Management Approach Documented in Living Project Management Plan

- Battelle ISO 9001 Compliant Quality Management System (QMS) includes SOP for PMP development and maintenance

- PMP must include plans for:
  - Integrated Change Mgmt
  - Management (WBS, schedule, cost, budget, deliverables)
  - Communications
  - Quality Management
  - Risk Mgmt/Risk Register



A detailed Work Breakdown Structure is a fundamental component of our task management process.

7. Project Management Approach Prime/Sub Interaction

- Fully Integrated Team
  - Composite Management Team
    - Ben Pierce, Matt Burns, Rob Zimmer, Daryl Taavola
  - Combined Offices
    - Management Team will all have offices in URS Minneapolis Office Space
  - History of Collaboration
    - Battelle and URS have worked together for more than two decades
  - Roles and Responsibilities
    - Ben Pierce (PM) provides guidance and overarching decisions; ultimately responsible for **ALL** project deliverables
    - Management Team provides PM with input, makes decisions with respect to particular area
    - Daryl Taavola – “Man on the ground” Operational Decisions

7. Project Management Approach Planned Relationship with Mn/DOT Project Manager and Team

- Planning for full integration
  - This is your project, we work for you!
  - Mn/DOT Project Manager and Team will be integrated with Battelle's Management Team
    - Participate in weekly and ad hoc team meetings
    - Active role in decision making, technical and non-technical issue resolution
- Open communication and dialogue
  - Mn/DOT can interact directly with anyone on Battelle Team
  - Daryl Taavola & rest of URS/Pierce Pini staff provide ready in-person access for Mn/DOT

7. Project Management Approach Level of Interaction with Program Participants

- Proposing a high level of interaction, but one that can be adjusted quickly based on need
  - Participant portal (telephone, e-mail)
  - In-person support at Pierce Pini's offices
    - Before and After Odometer Readings
  - Pre-deployment telephone conversation
    - Confirm willingness to participate
    - Answer questions
    - Provide a contact link/personal connection for future interactions
  - Post-deployement
    - All of the above!

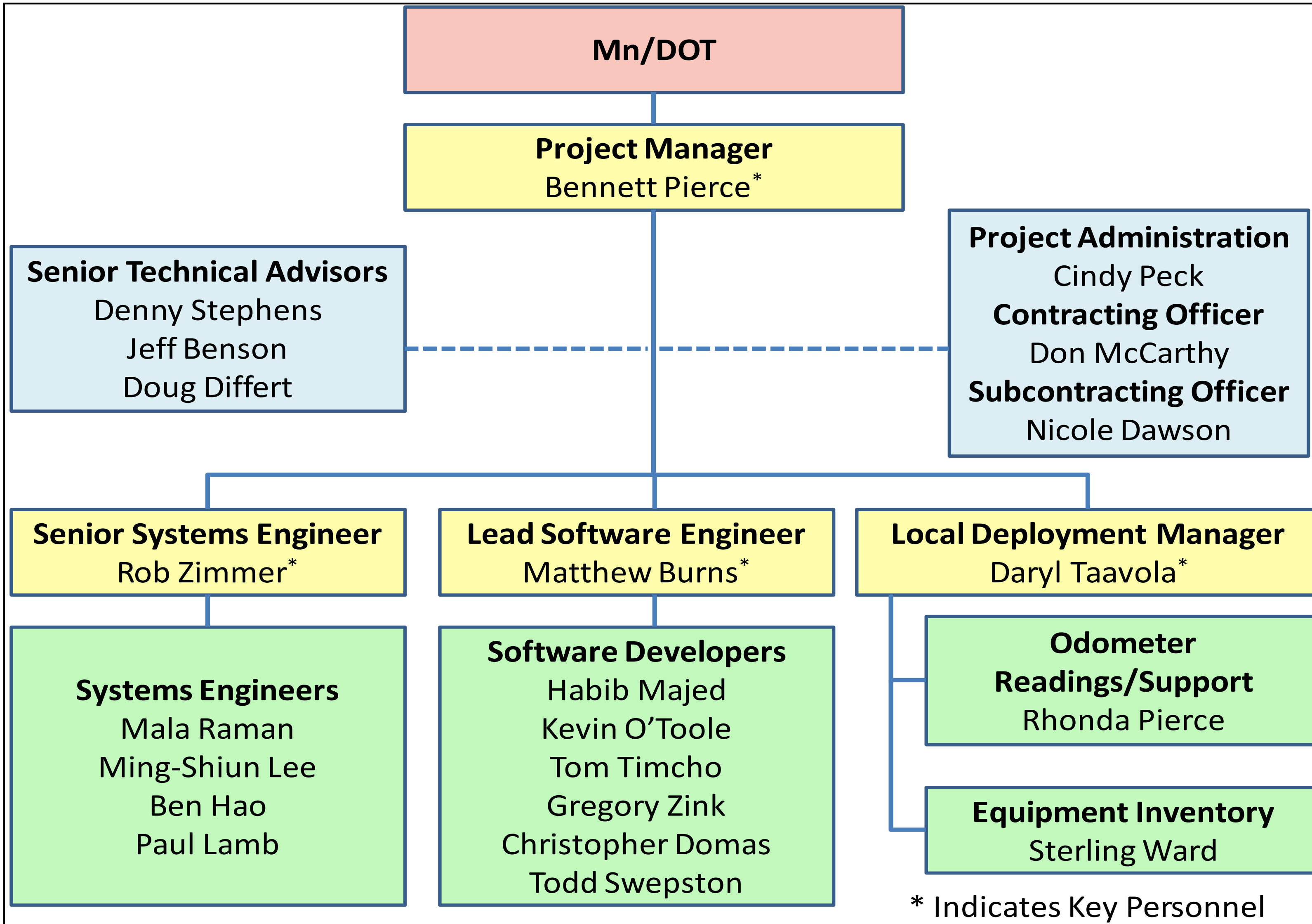
Battelle Team Benefits

- Comprehensive system design and implementation
  - Scalable and Modular
  - Cost effective solution
  - Reduces time needed for wider deployment
- Experience
  - Not our first IntelliDrive or GPS equipment development/deployment project
  - Understanding of vehicle technologies in the real world
- Enthusiasm and Ownership – critical for success
  - Battelle heavily invested in IntelliDrive
  - URS have been supporting Mn/DOT with ITS for two decades

QUESTIONS AND ANSWERS

BACKUP SLIDES

Project Staff Organization



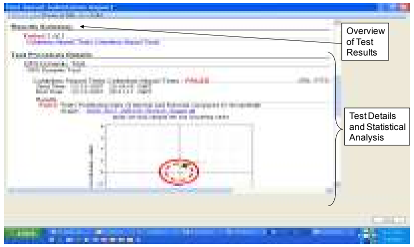
Proposed Staff Are Highly Qualified and Experienced

Proposed Key Personnel	Overview of Qualifications
Ben Pierce Project Manager	▪ Experienced managing large field deployment of in-vehicle GPS devices ▪ Experience with IntelliDrive[SM] applications, hardware/software, and analysis
Rob Zimmer Systems Engineer	▪ PI & Lead Systems Engineer, VII POC ▪ Senior Systems Engineer, wireless roadside inspection program for FMCSA
Matt Burns Software Engineer	▪ Extensive experience with software development and COTS hardware ▪ C#, Java, Visual Basic, C++, ASP.NET, Perl, SQL, XML, HTML, and Javascript
Daryl Taavola Local Deployment Manager	▪ Professional Engineer/Minnesota/ 26131/1998 ▪ Principal-in-charge for Mn/DOT Mileage Based User Fee project

Experience of Key Staff

US DOT IntelliDrive℠ Proof of Concept

- Requirements and testing development
- Completed Raytheon's work when they were removed from the project by US DOT/VIIC
- Lead Systems Integrator
  - Hardware Integration
  - Software development, testing, and integration
- Recognized leaders in data management and analysis (Public and Private tests/analysis)



Field Deployment of GPS Devices to Capture Vehicle Movements (ODOT, SCAG)

- Battelle developed first ever GPS device to capture vehicle movements as part of household travel surveys
- GPS Leader device deployed in two HH surveys (> 1,500 vehicles)

Battelle's GPS Leader™

Other Experience

- Battelle
  - Hazmat Tracking System-Expanded Satellite-Based, Mobile Communication System (Satellite communications)
  - Wireless Roadside Inspection Program (RFID/Transponders)
  - Border Delay and Crossing Times at the U.S. – Mexico Border – Part II (RFID Technology)
- URS
  - Mn/DOT Mileage Based User Fee Project
  - Georgia CellINT Cell Phone Research Project (Cellular)
  - Minnesota DOT Guidestar ITS Program
  - San Mateo Projects Smart Corridor Program
  - Staff provided leadership in establishing Mn/DOT MnPASS Program

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Proposed Staff = Project Staff

Proposed Key Personnel	% of Time Dedicated to Project (Hours)*	% of Time on Project During Execution of Responsible Tasks
Ben Pierce Project Manager	87% (4,350 hours)	**87%**
Rob Zimmer Systems Engineer	15% (750 hours)	**62%**
Matt Burns Software Engineer	36% (1,815 hours)	**66%**
Daryl Taavola Local Deployment Manager	20% (1,000 hours)	**20%**

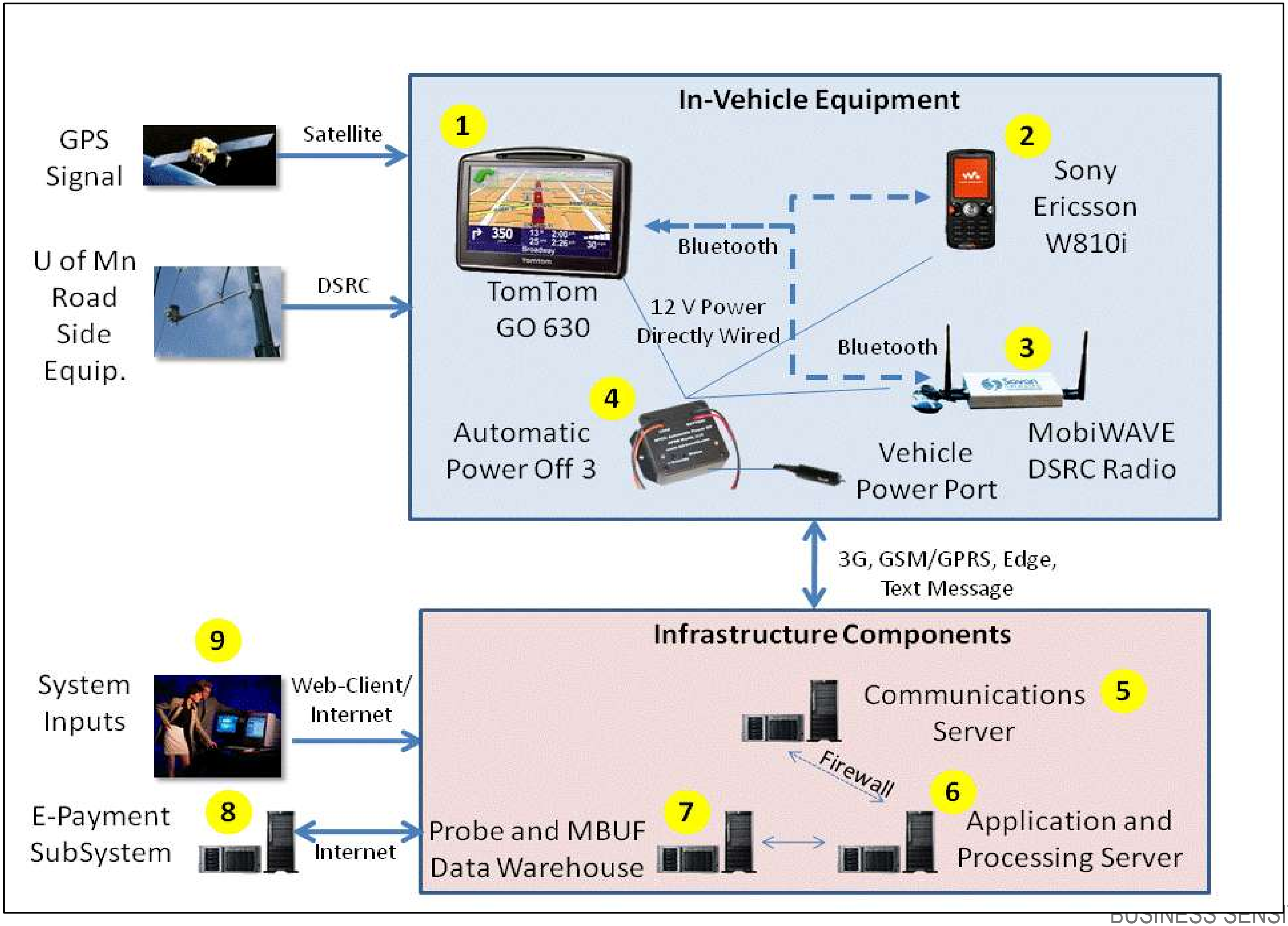
* Assumes a 29 month period of performance

OVERVIEW OF SYSTEM DESIGN - HARDWARE

System Design – Guiding Concepts

- Implementable quickly
  - Existing COTs hardware (PND, Cell-phones, etc.)
  - Avoid complex installations
  - Include ability for Mn/DOT to implement in stages – update on-board systems during operations
- Provide Mn/DOT operational flexibility
  - Avoid "locking" into single communications provider
  - Concepts expandable to other COTS devices as made available
- Minimize long term operational costs to Mn/DOT
  - Recognize role of public/private partnerships for providing services (traveler information, e-payment, etc.)
  - Balance costs to Mn/DOT & participants with benefits
    - No infrastructure deployments needed by Mn/DOT
    - GPS accuracy, time-to-position fix, extent of equipment, etc.

Overview of Proposed System Design



Example of Future Hardware that Can be Easily Integrated: Bluetooth OBD-II

- Allows for wireless connection to OBD-II DLC
- Eliminates need for physical wiring, which could present safety hazard

Courtesy: dealextreme.com

System Design – Why Tom/Tom?

- TomTom
  - Open OS system (Linux)
    - Relatively “low overhead” OS – increases amount of processor available to applications
    - OS used by major PNS providers (TomTom, Garmin)
  - Easy to access navigation corrected GPS coordinates
    - Snapped to road
  - Provides flexibility on cost versus features
    - Low cost solution, TomTom One 130 = $75
    - High-end solution, TomTom Go 930 = $550
      - Integrated traffic, improved time to GPS signal, larger memory/processor
  - Durability and Field Proven
    - Established personal navigation device provider
  - Separating cell-phone from navigation for safety

What other possibilities did we consider?

- Other Portable Navigation Devices
- iPhone or Droid Enabled Phone with Navigation Software
  - Droid “too new” not proven as stable OS
  - iPhone
    - Stable platform, integrated GPS, Navigation software capable
    - High-end of cost ($200 + 2 year service), Advanced OS (proprietary)
    - Not all iPhones have GPS capability
    - Some concern over GPS accuracy (average median error of 8 m for ten 20-minute field tests
      - Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi, and Cellular Positioning, Paul A Zandbergen, *Transactions in GIS*, Volume 13 Issue s1, Pages 5 – 25
    - **Safety/Liability – Distracted Driving**
- Garmin
  - Similar to TomTom, slightly harder to obtain map corrected GPS coordinates

Other Possibilities

- Satellite Communications (OnStar, Qualcomm)
  - Not widespread use, proprietary systems
- RFID, Transponders, DSRC
  - Used extensively in Europe for tracking vehicle movements/fees
  - Commonly used in US tolling facilities
  - Requires extensive roadside infrastructure (readers)
  - Only can capture data where infrastructure exists
- Wi-Fi
  - Possible in Minneapolis because of large Wi-Fi coverage
  - Not as common in other areas – limits probe data collection
  - Significant "handshake" needed for communications
  - Possible backup to cellular coverage – especially as personal wi-fi networks gain in popularity
    - Register you car with your home network

OVERVIEW OF SYSTEM DESIGN - SOFTWARE

Conceptualization of Software

- Vehicle ignition
- Mileage Based-User Fee application
- Probe data application
- In-vehicle signage application
- Traveler information application
- Vehicle shutdown

Processes at Vehicle Ignition

Vehicle Ignition

1 APO3 Senses Power Surge Supplies Power to TomTom, Phone, DSRC radio

2 Equipment Performs Power-up Procedure

3 TomTom Starts Software:
- Navigation
- MBUF
- Probe
- Signage
- Communication/Positioning

4 Bluetooth Communications Established

5
- Vehicle Registers
- Receives Updates
- Buffer contents sent

Mileage Based User Fee Application

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	Action	Result
1	 Vehicle Ignition	**In-Vehicle Device Setup Completed** APO3 Senses Ignition & Provides Power → Signals Acquired → Device Registers → Updates Received
2	MBUF Application Subscribes to Navigation/ GPS Output	**Navigation Records Received** Latitude, Longitude, Date, Time, City, Road Name, Altitude, Speed **"-832035|3998765|2000-01-04, 23:09:59, Grandview Heights OH, W 5th Ave, alt=227.7|0|"**
3	MBUF Application Queries on-board Database Developed by Battelle Team	**Mileage Based User Fee Assigned** Matched on City/ Road Name or Matched on Geo.Area(s) or Default Fee Assigned
4	MBUF Application Accumulates Fees by Road Classification/Geo. Area	**Cumulative Mileage Based User Fee Updated** Linear Distance from last GPS calculated → Miles & Fees Aggregated in On-Board Temp Database
5	Vehicle Turns onto Different Roadway	**Steps 2-4 Repeated to Update Mileage Fee**
6	Vehicle Shut Down	**Cumulative Mileage Based User Fee Submitted** Submitted if in coverage Buffered if not in coverage

Probe Data Application

- Probe data collected every 20 seconds regardless of location
  - Except if “turned off” by participant
- Multiple navigation points every second generated
  - Probe snapshot will consist of most “recent” navigation data and running average of past 3-5 navigation points
- Probe snapshots will be in J2735 compatible format

thePosition{
utcTime {year XXXX,
month XX,
day XX,
hour XX,
minute XX,
second XX},
longitude -664100940,
lat 319878854,
elevation 3269,
heading 31247,
speed 1447,
}
EvaluationDoc{
MessageID XXXXXXXXXX,
SnapshotID XXXXXXXXXX}

RSA Encryption

-----BEGIN PGP MESSAGE-----
Version: GnuPG v2.0.12 (MingW32)
hQEOA9i1/oGW1vthEAQAsClLMtURwT1SN/p24Kk+9/FJh0FWX36B4
3kkjDrm5euKS30r9PTsMFYrFJ6RM4wka4+eJxbL5/8HQRhW/rpVMbE
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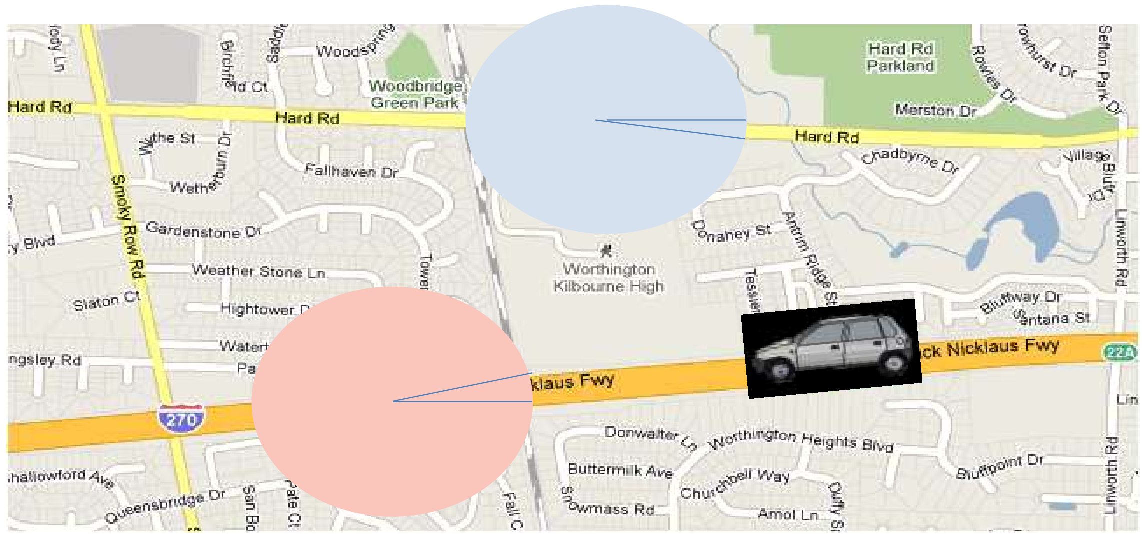
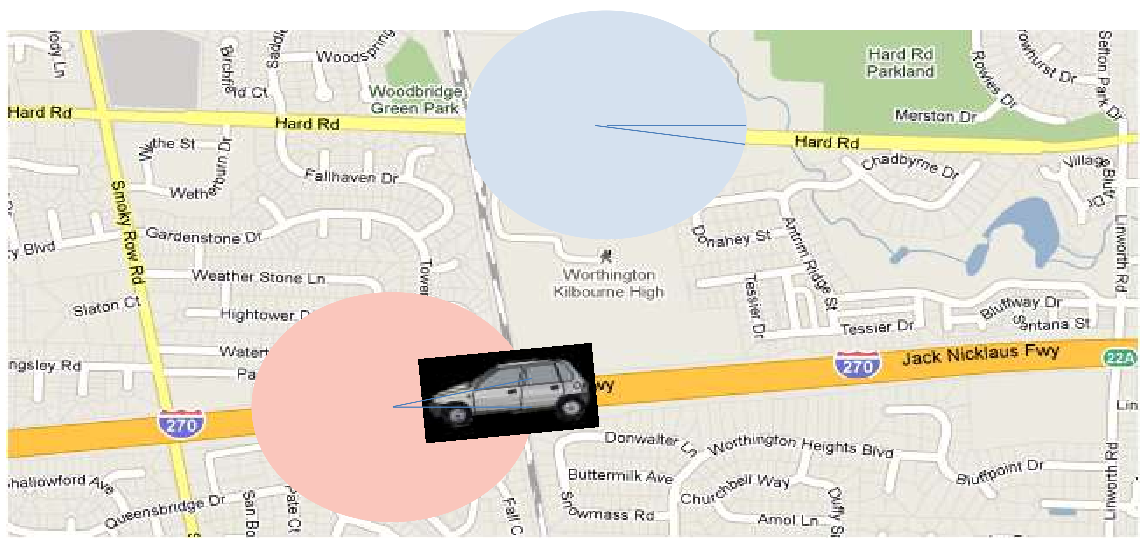
-----END PGP MESSAGE-----

In-Vehicle Signage Application

1. Application subscribes to navigation output
2. Updates temporary heading/position buffer
3. Compares current position to defined zones of interest
4. Identifies subset of zones based upon linear distance
5. Compares criteria to determine if and what sign needs to be displayed:
   - −Radius of zone
   - −Lat/Long of zone centroid
   - −Type of Zone
   - −Audible/Visual Display
   - −Heading criteria
   - −Duration of notification.
   - −Min/max speed
   - −Day of week
   - −Time range
   - −Priority
   - −Date range





In-Vehicle Signage Application

- Proposing two types of signage notification
  - TomTom “Points of Interest”
  - Dedicated full-screen display

Traveler Information Application

- Operationally treated as "signage" messages by in-vehicle equipment
- Real-time traffic updates provided via TomTom Traffic Plus™ or other subscription service
  - INRIX is backend provider of TomTom service
- Probe data could easily be used to compare actual versus historical traffic flow data
  - Was not originally intending to provide this in real-time to participants due to reliability issues (i.e., sample sizes), could be done if desired by Mn/DOT
  - Will develop analysis application and historical traffic flow database for comparison and further algorithm refinement
  - We recognize independent vendors already provide this service either free or through subscription
    - INRIX, Traffic.com

Processes at Vehicle Shutoff

Vehicle Shutoff

1

APO3 Senses Power Dip Stops Supplying Power to Devices After 10 minutes

2

Equipment Sends MBUF Report

3

- Received MBUF Submission verification
- Resends or Buffers
- Vehicle Unregisters

Equipment Performs Shutdown Procedures

4

BACKUP SLIDES FOR INTERVIEW TOPICS

1. Establishing Pricing Zones/Fee Structure for MBUF: Zone Establishment (cont.)

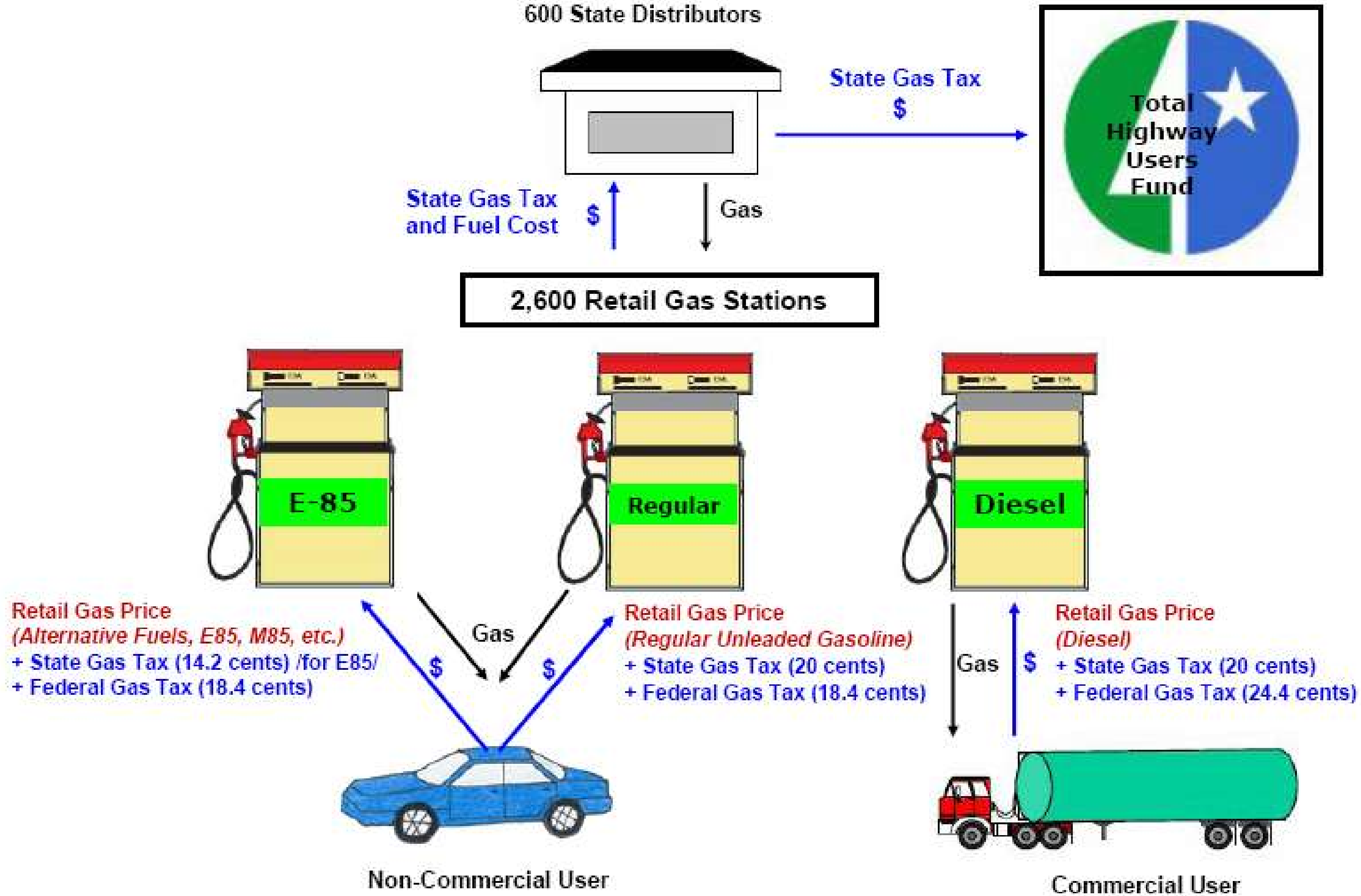
Battelle
The Business of Innovation

Some Examples…

Road Facility	Location	Time of Day/ Day of Week	Direction of Travel	ADT	Vehicle Type	Fee / Mile
Interstate 94 Brooklyn Pk	Henn. Co - Urban	Wed – 8 am	EB	>100,000	SOV	$0.04
TH 15 St. Augusta	Sterns Co – Rural	Thur – 11 am	WB	>10,000	Truck	$0.03
CSAH 39 Monticello	Wright Co – Suburban	Tue. 7:30 am	EB	>20,000	SOV	$0.025
Division St Buffalo	Wright Co - Rural	Mon – 8 pm	WB	<5,000	SOV	$0.02

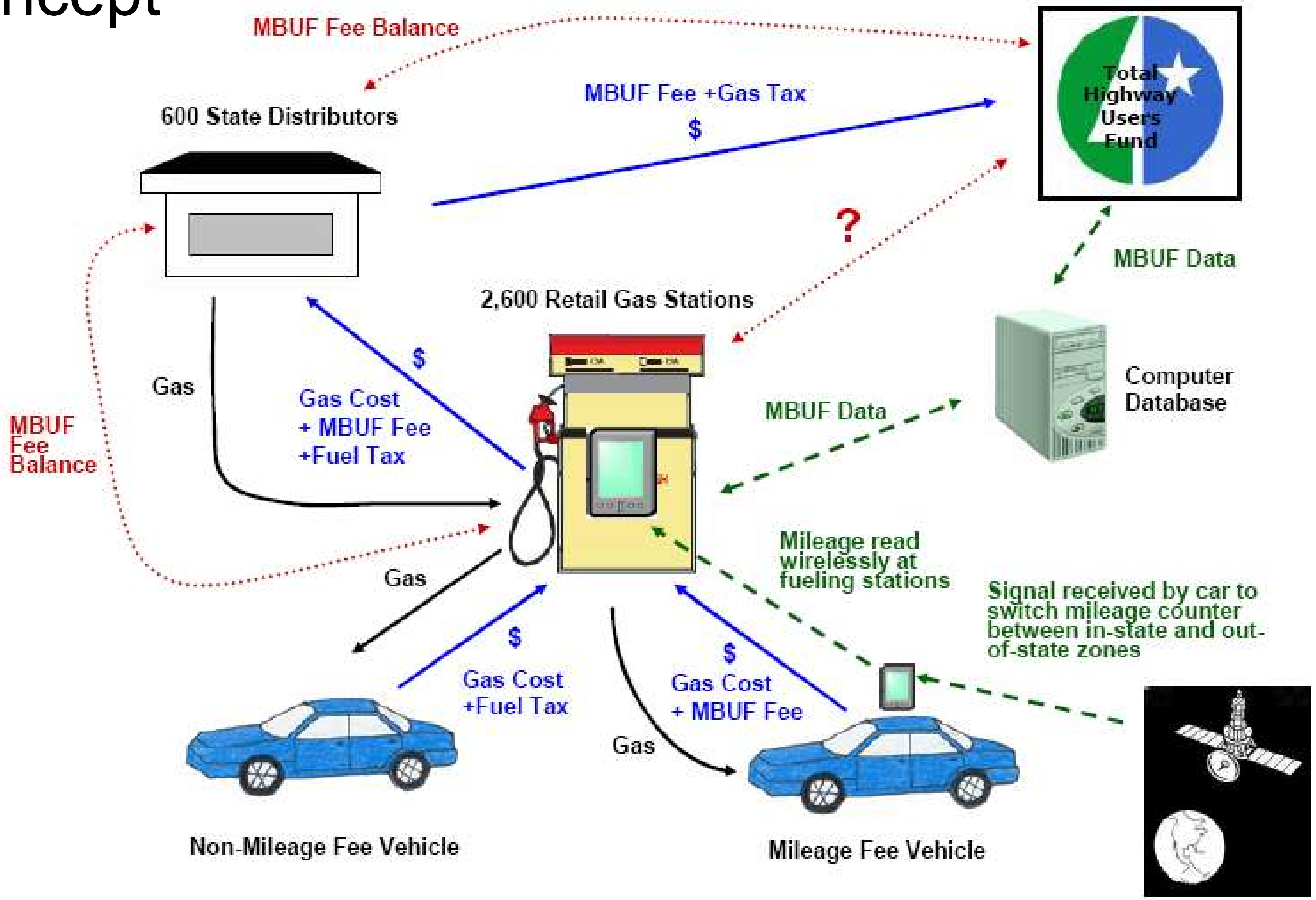
Revenue Collection Process

- Minnesota state of operations

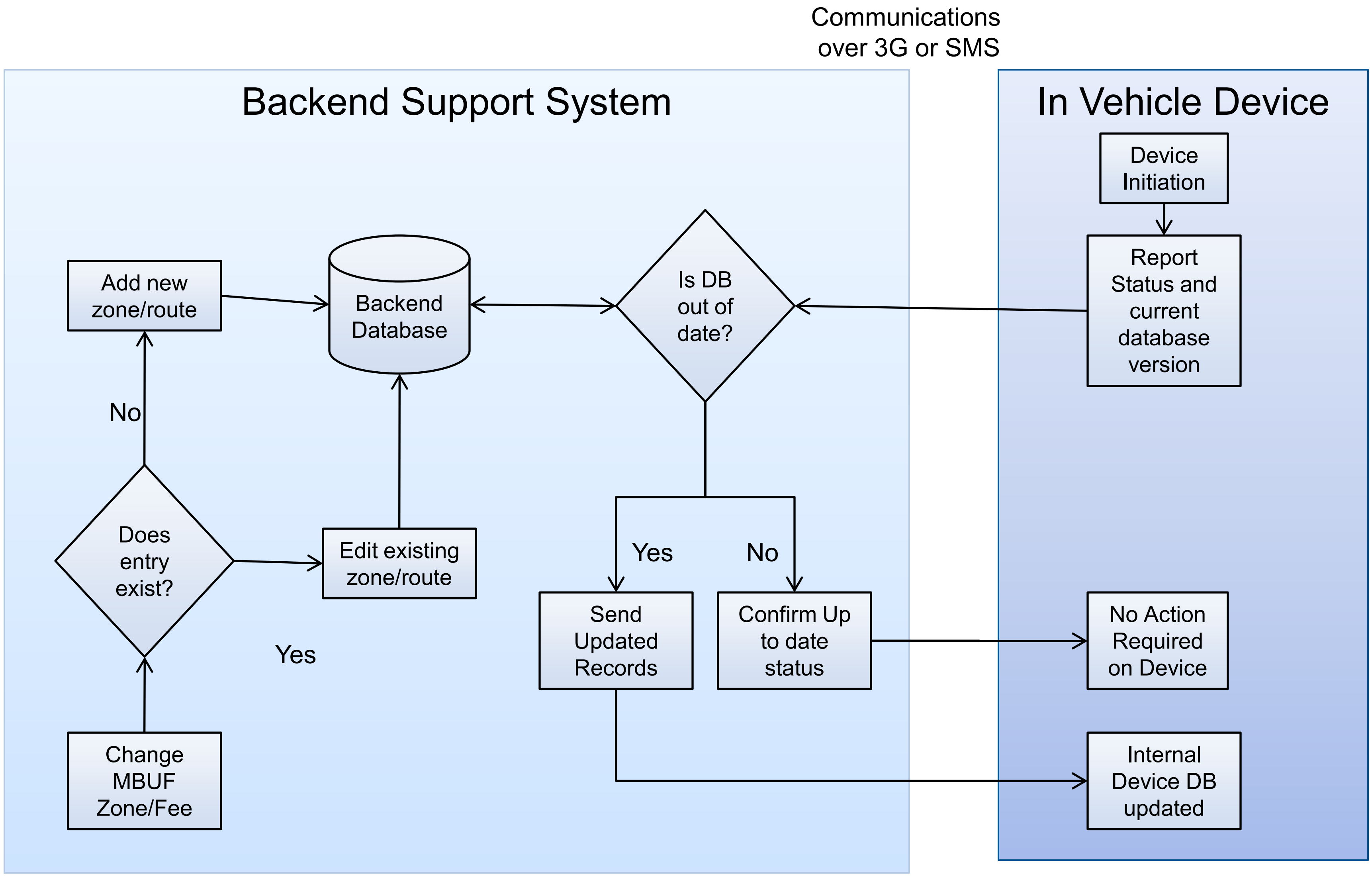


Future Revenue Collection Process?

- Concept



1. Establishing Pricing Zones/Fee Structure for MBUF:
Process for Zone/Fee Structure Modification (cont.)



BUSINESS SENSITIVE