# EXPLORER:
# Long-Range Untethered Real-Time Live Gas-Main Inspection System

Natural Gas Infrastructure Reliability Industry Forums

NETL - DOE

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Presented by: Dr. George Vradis

# BACKGROUND

- Cameras are used for visual inspection of pipes for:
  - Condition monitoring
  - Maintenance and/or construction planning
- Presently cameras are tethered and cannot negotiate turns, thus providing limited range of operation (less that 250 ft from launching point)

***GasCam Video Inspection System***

Probably most popular gasline video inspection system today

# PRIMARY INCENTIVES/DRIVERS

- Increase range of operation of cameras in order to:
  - Reduce excavation costs
  - Reduce operational costs
  - Increase range of applications
- Develop a versatile modular system to deploy other instrumentation and/or repair tools; not just a camera

# OBJECTIVES

- Develop a tele-operated long-range untethered video-inspection system for live distribution mains
- 6” and 8” pipes
- Able to negotiate 90 deg turns and vertical elements
- Battery powered with long battery life
- Wireless communication with long range
- Range-extension through in-situ keyhole recharging
- Modular design that will allow for future expansion of capabilities

# BENEFITS - Quantitative

- Inspection of a 1500 ft long pipe segment using Explorer would cost 30 – 50% less than using existing technology (Aries camera)

  Assumptions:

  $1,000/day for Aries,  $2,000/day for Explorer

  $1,000 to $2,500 per excavation

  $300 ft/day for Aries

  $1500 ft/day for Explorer

  $1,000 access fitting left behind

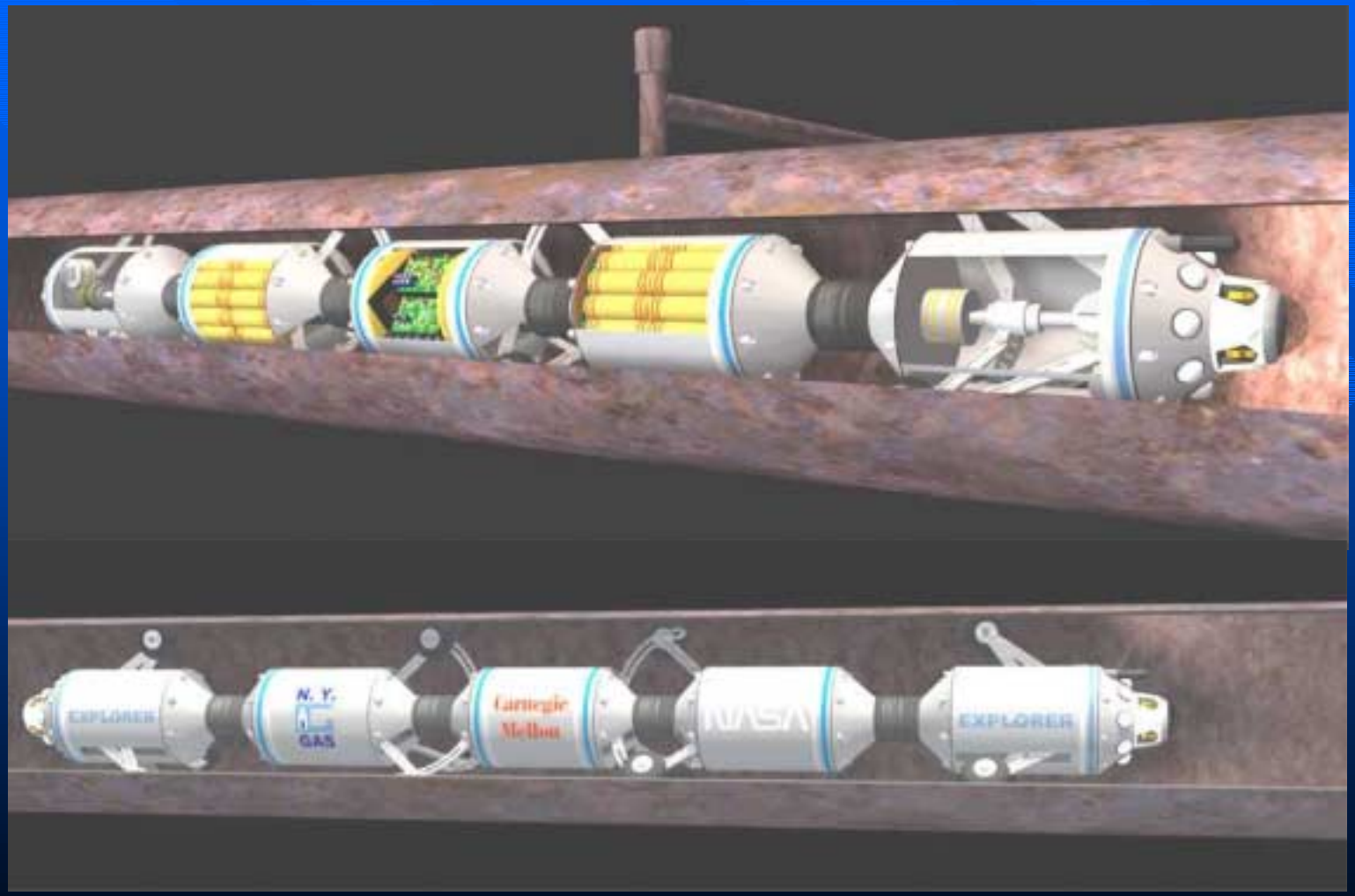
# BENEFITS - Qualitative

- Explorer will be able to inspect non-straight pipe with:
  - Expansions/contractions
  - Bends and tees
  - Vertical segments
- Modular design can expand its field of use dramatically in the future

# WORKSCOPE

- Phase I: Feasibility study and preliminary design (completed)
- Phase II:
  - Final design (completed)
  - Prototype construction (nearing completion)
  - Lab testing (under way)
- Phase III: Field demonstrations

# EXPLORER Configuration



# EXPLORER Configuration (continued)

# Explorer
# Physical Descriptors

- System Length – 50”
  - Module Length limited by 90º elbow, 6” ID pipe, 4” Body O.D
  - 5 Modules (2 drivers, 1 Electronics, 2 Battery) + Conn.
- Weight - 35 lbs.
- Locomotion Speed – 4.5” per sec horizontal
  - Based on highest-density Li-Ion rechargeable pack-size
  - Can covers about 2 miles in an 8-hr. day
- Recharge – Topside or via coupling

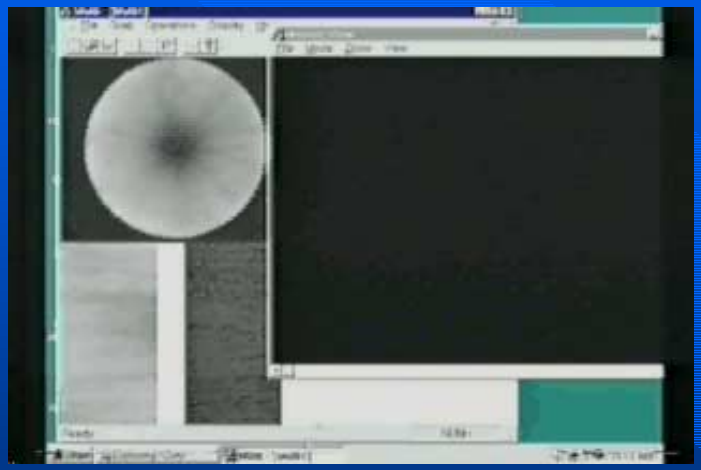
# EXPLORER Configuration Locomotor

- Able to climb vertical pipe segments
- Able to negotiate 90 deg-turns in 6” and 8” pipes
- Able to center itself in the pipe
- 3 drive-wheels on articulated linkage driven by brushless DC motor

# EXPLORER Configuration Camera

- Camera system
  - Two fisheye cameras; one on each end
  - 190-deg field of view
  - Miniaturized and rugged
  - Dewarping & mosaiquing software for better images of the pipe wall

# EXPLORER Configuration
## Camera (continued)



# EXPLORER Configuration Wireless Communication

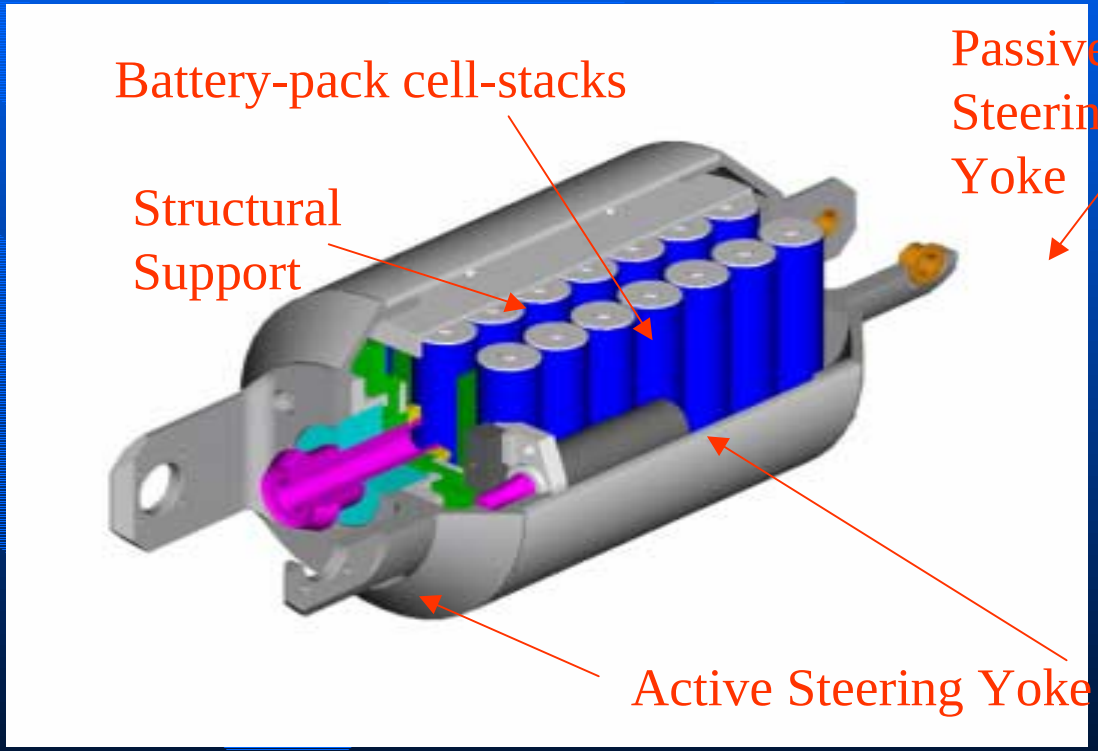
- Wireless module
  - off-the-self wireless technology
  - performance in lab set-up and field demos very encouraging

# EXPLORER Configuration Wireless Communication (continued)

- OEM Wireless PC LAN-Card
  - 2.4GHz (IEEE 802.11b)
  - Range-extending antenna
  - Exchangeable as OEM-frequencies increase

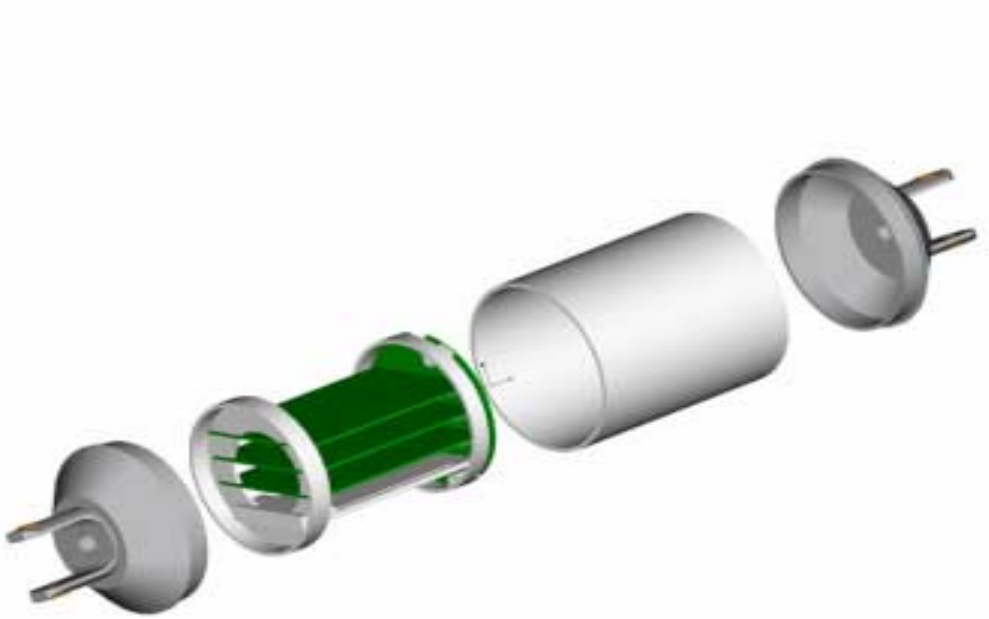
# EXPLORER Configuration
# Power Supply

- Rechargeable Li-Ion
  - 67x17mm C Panasonic
  - Integral PCB Control
  - NOT sealed but purged
  - Structural mounting
- Alternative – NimH Stand-in



# EXPLORER Configuration Computing

- Navigation Computer
  - Hitachi SuperH (HSH) running LINUX OS
- Communication Adapter
- Video Processing
- Support I/O
- Interface & Communications Bus
- Video & Antenna Switch



# EXPLORER Configuration Computing (continued)

- Hitachi SH-4 “SuperH”
  - 32-bit, superscalar RISC microprocessor
  - Up to 1000MIPS per Watt
  - Four power-down states (down to 25 mW)
  - 2.5W(Max) @ 200MHz
  - Integral Memory bus controller

# EXPLORER Configuration Launching System

- Taping via Mueller C1-36 system
- Special launcher designed; under construction
- Features
  - » Vertical entry, no-blow, high pressure
  - » Sealed and Purgeable
  - » Deployable Antenna
  - » Built-in charger & comm-interface connector
  - » Jib-crane deployable

# EXPLORER Configuration Launching System (continued)

- Mueller C1-36 Line
  - » Weld-on Line Stopper Fitting
  - » Machine Adapter
  - » C1-36 Drilling Machine
  - » 9” Gate Valve
  - » Power Plant
  - » Completion Machine
  - » One-time Cost: $40,712
- Left-behind buried fittings: $1,308 (6”) to $1,936 (8”)

# EXPLORER Configuration User Interface

- Portable Case
  - » Embedded PC104 CPU
  - » Ethernet Antenna Cable
  - » High-Resolution Display
  - » Integral Joystick
  - » Alphanumeric Interface
  - » Custom GUI

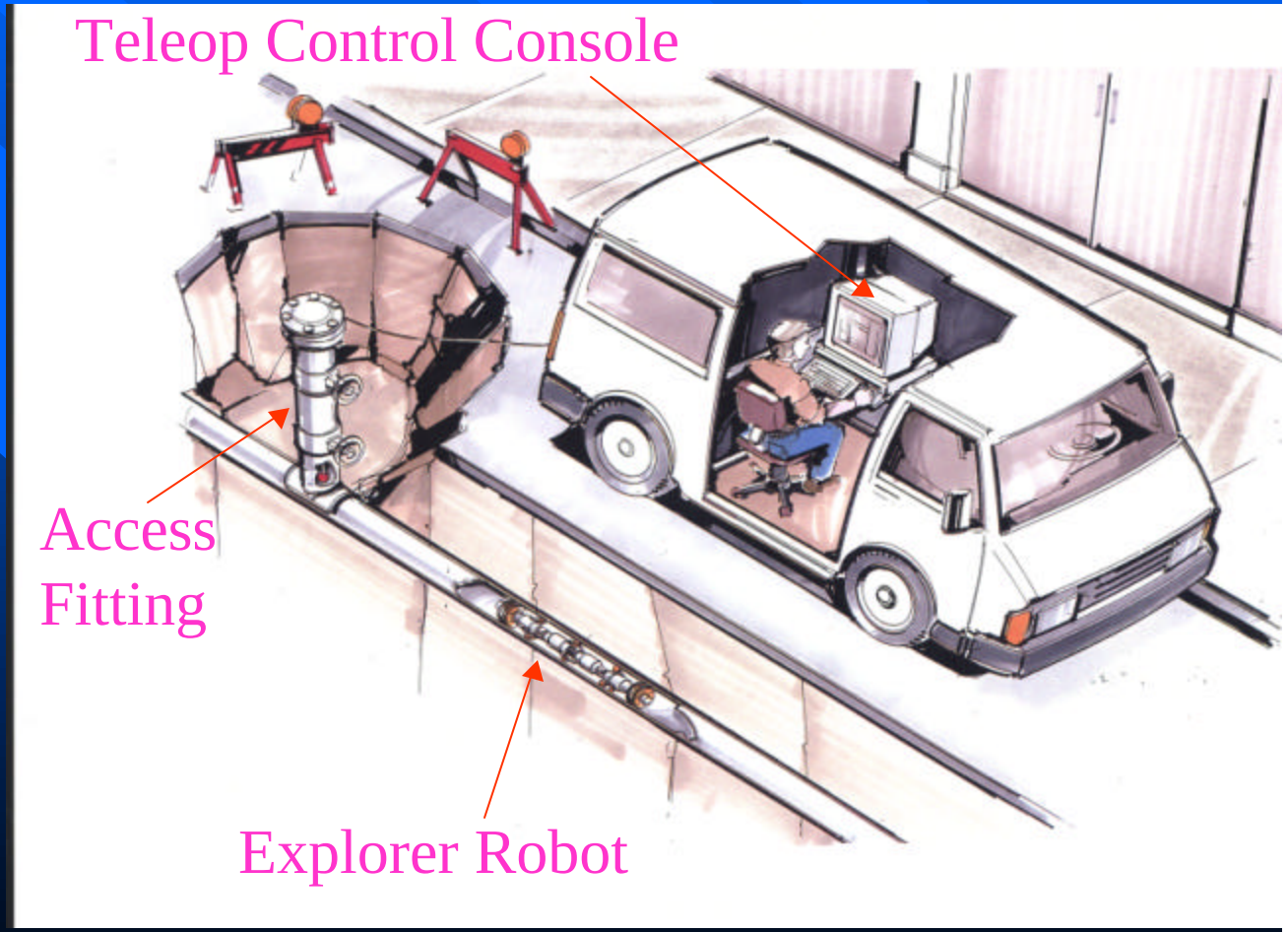
# Explorer Robot Deployment

**Day 1**

08:00 • Drive up & dig hole
12:00 • Install Launcher
15:00 • Wake-up Robot
15:15 • Test Launcher & Comm
15:30 • Test Robot
16:00 • Secure System

**Day 2**

08:00 • Show up at Job-Site
08:30 • Wake up Routine
09:00 • Launch Robot
** Travel 10,000 ft RT*
16:30 • Retrieve Robot
17:00 • Secure & Charge Robot




**Day 2 + (1<N<3)**

# OPEN ISSUES/RISK

- Ability of locomotor to make 90-deg turns demonstrated; optimization of turning routines underway
- Performance of wireless system in real piping systems very promising; still being evaluated
- System integration issues appear manageable
- Development of recharging and antenna deployment systems to be considered during commercialization effort

# SCHEDULE

| | |
|---|---|
| Design finalization and drawings | completed 12/01 |
| Wireless testing in field | completed 12/01 |
| Prototype building | in progress |
| Testing in lab and improvements | by 3/03 |
| Delivery of prototype to funders | by 5/03 |
| Field demos | by 10/03 |
| Identification of commercialization partner | in progress |