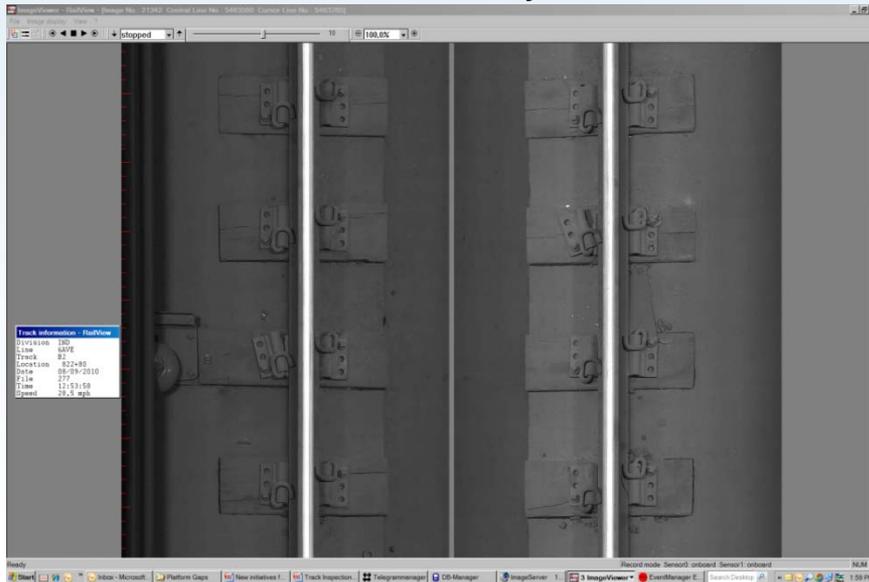




NYCT's Track Geometry Car - TGC4



TGC4's Rail View Video System

FTA Office of Research  
Project  
NY-26-7112

# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot



# NYCT's Automated Track Inspections

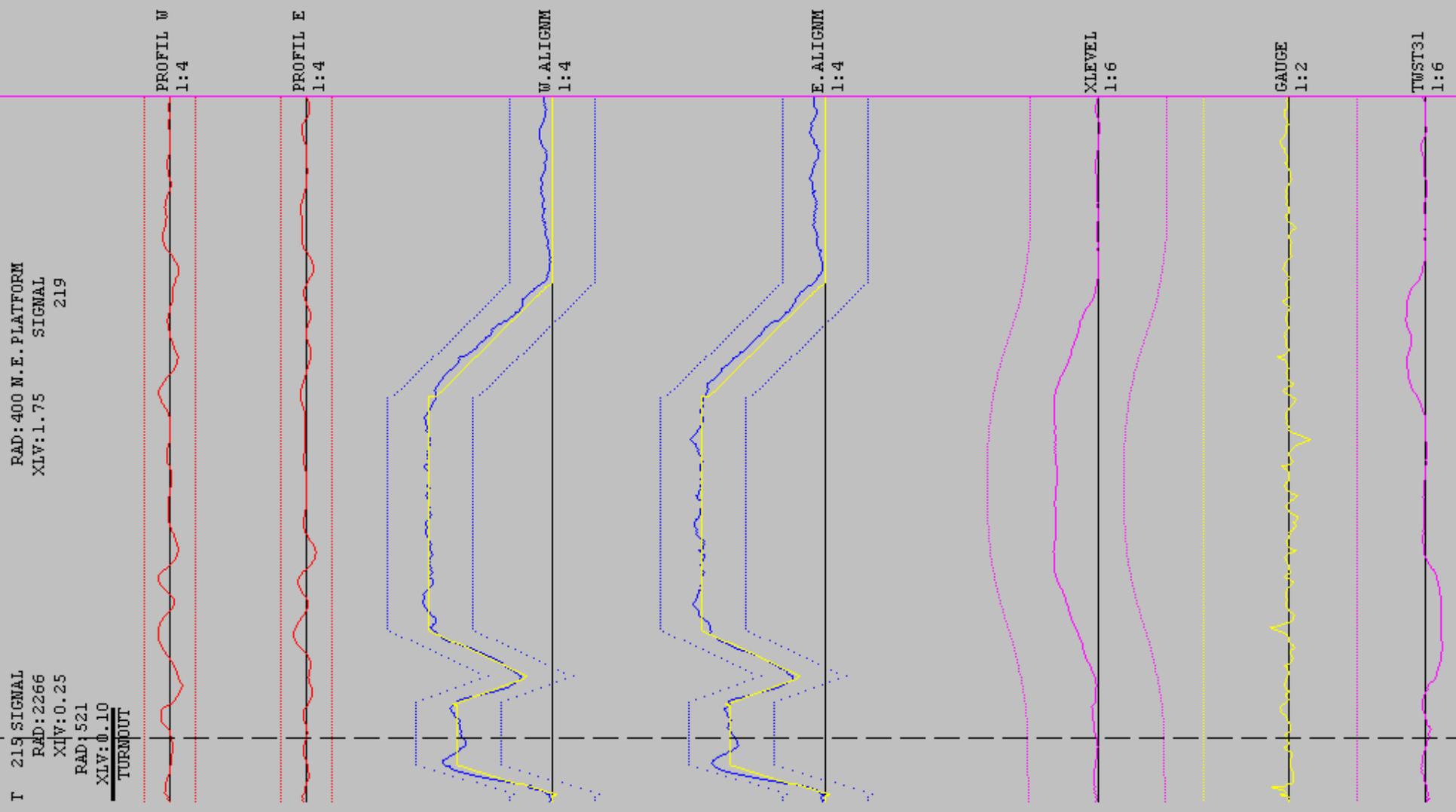
## Track Geometry Cars (TGC3 and TGC4):

- Measure track geometry under dynamic loads at all speeds
- Can also measure:
  - Thermal Imaging
  - Rail wear
  - Third Rail gauge & height
  - Flangeways
  - Tunnel clearances
  - Rail Flaws (Ultrasonic Detection) (TGC3 and TGC4)
  - Tunnel 3D “point cloud” scanning (TGC4 car only)
  - Rail View / Side View Video Inspection (TGC4 only)



# Track Geometry Chart

Events



214+54	Division	IRT	Subdivision	A
	Line	7AVE	Sequence	DOWN
	Loc. From	SOUTH FERRY	Loc. To	N/O SOUTH FERRY
	Track	V1A	Time of Day	12:48
	Class	RED	Date	11/26/2008

# Rail Profile and Rail Wear

Rail Profile Client [rail.cfg] NYC2

File View Help

CAR TGC4

Division	BMT	Subdivision	B1
Line	4AVE	Sequence	DOWN
Loc. From	95TH ST	Loc. To	DITMARS BLVD
Track	F2	Time of Day	18:12
		Date	06/02/2011
File	2_06022011_10020	Track Dir	NORTH

**Left Rail Profile**

100 LB ARA-B NYCTA

**Head Loss**  
0.45 sq in

**Loss Percent**  
11.62%

599+96 (ST/Ft)

Lip	0.016	Cant 1/40	0.431
Height	5.285	Wear-Height	0.355
Width	2.664	Wear-Width	0.000
G-Width	1.309	Wear-GWidt	0.000

Correction Off

Hold

Zoom In Zoom Out

Print

**Right Rail Profile**

100 LB ARA-B NYCTA

**Head Loss**  
0.78 sq in

**Loss Percent**  
19.95%

599+96 (ST/Ft)

Lip	0.000	Cant 1/40	-0.018
Height	5.285	Wear-Height	0.355
Width	2.602	Wear-Width	0.016
G-Width	1.258	Wear-GWidt	0.055

GAU:56.516

MGA:55.484

\*\*\*\*\*

Division	IRT	Subdivision	A
Line	7AVE	Sequence	DOWN
Loc. From	SOUTH FERRY	Loc. To	N/O SOUTH FERRY
Track	V1A	Time of Day	124803
Class	RED	Date	11/26/2008

# Tunnel Clearances Measuring System

218+31 (ST/Ft) 6 IRT

COMPX=1.73

COMPY=51.81

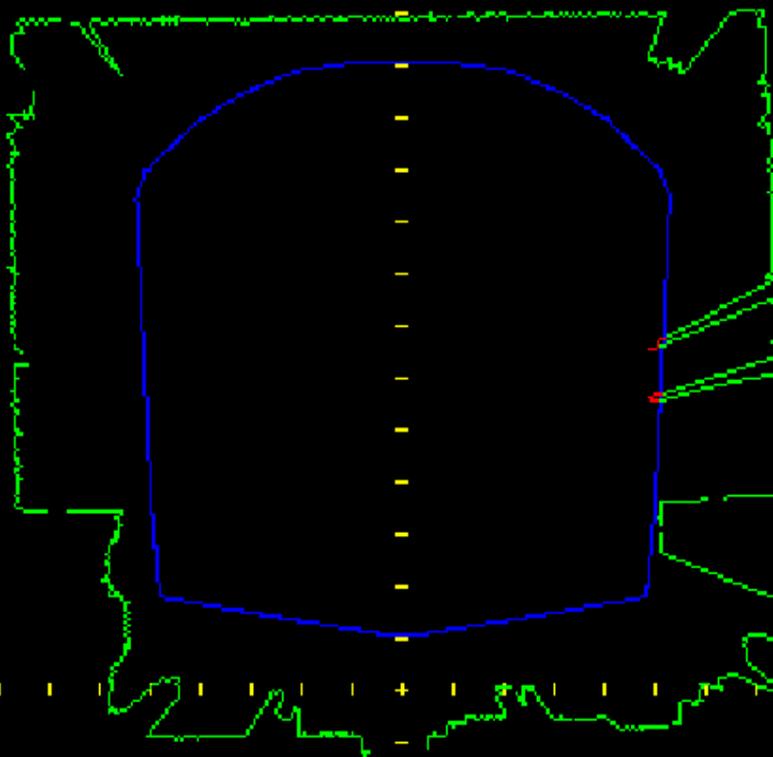
CRU=0.47

RAD=3075.2

SUP=-0.03

GAGE=0.07

RPS=24



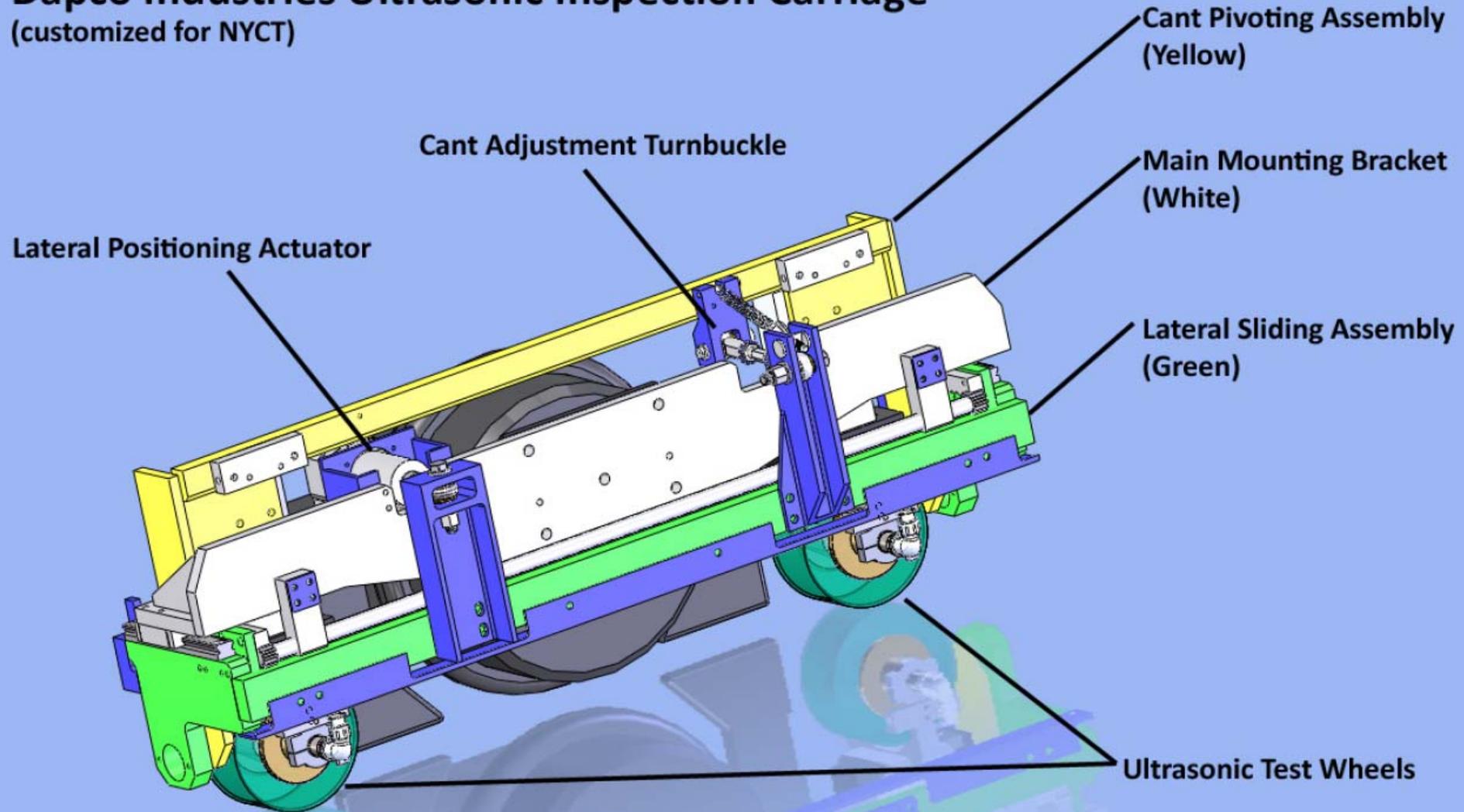
# Thermal Imaging System



Hot Third Rail Insulator in Wet Area

# DAPCO UT Rail Flaw Detection Equipment

## Dapco Industries Ultrasonic Inspection Carriage (customized for NYCT)





Head Web Base Break on Field Weld



# Right-of-Way Video System

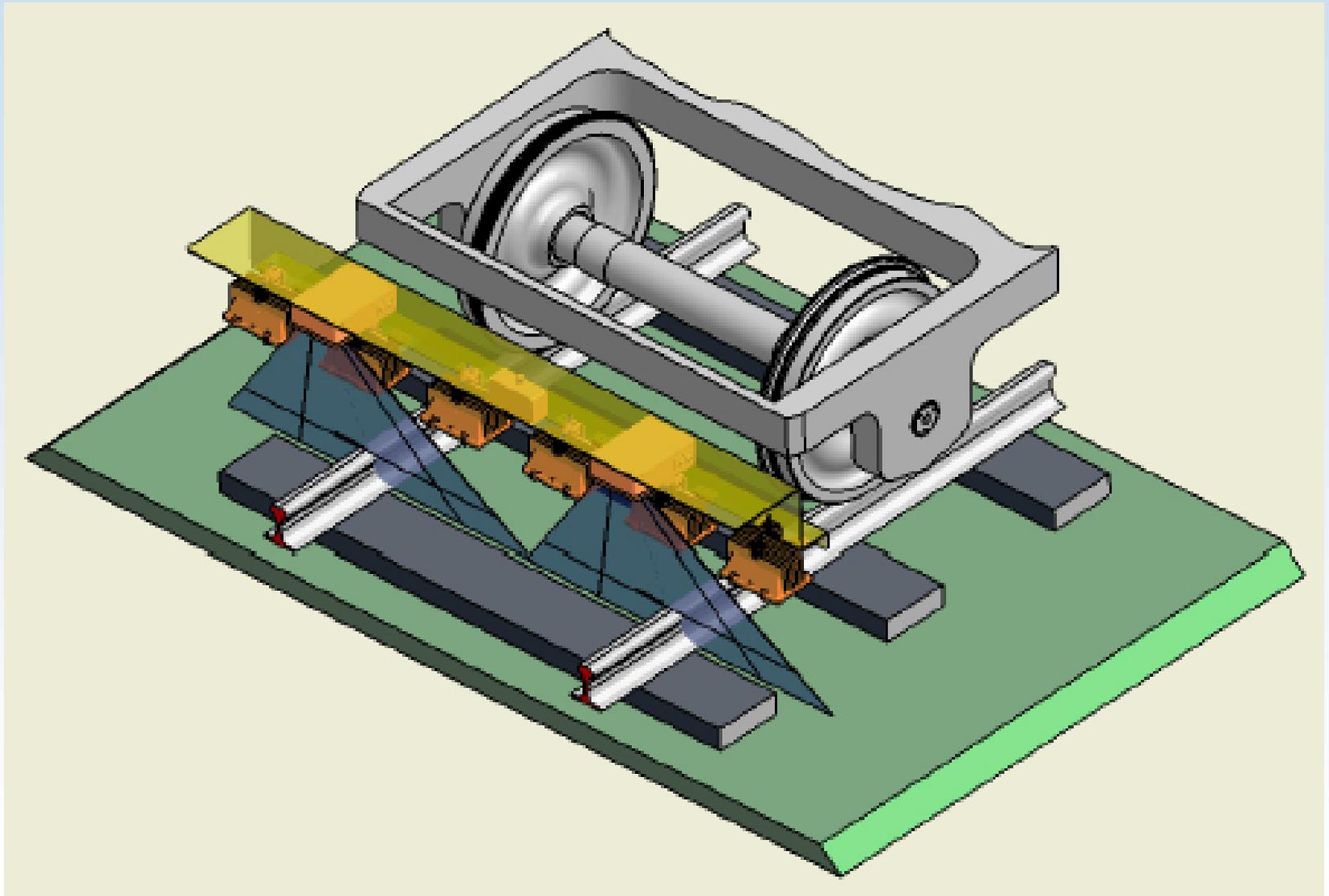


04:55



Track ML – City Hall Loop – Old City Hall Station – Middle

# Rail View Video System



*Conceptual Layout of the Rail View Video System's Cameras and Lights*



# Example of Rail View Video System

The screenshot displays the RailView software interface. The main window shows a video feed of rail tracks with two red boxes highlighting specific areas of interest. The interface includes a menu bar (File, Image display, View), a toolbar with navigation and zoom controls, and a status bar at the bottom. A 'Track information - RailView' panel is visible on the left side of the video feed.

Track information - RailView

Division	IND
Line	6AVE
Track	B2
Location	822+80
Date	08/09/2010
File	277
Time	12:53:58
Speed	28,5 mph

Ready | Record mode | Sensor0: onboard | Sensor1: onboard | NUM

Start | Inbox - Microsoft... | Platform Gaps | New initiatives f... | Track Inspection... | Telegrammanager | DB-Manager | ImageServer 1... | 3 ImageViewer | EventManager E... | Search Desktop | 1:59 PM



# 150% Zoom of the Rail View video system

ImageViewer - RailView - [Image No.: 21342 Central Line No.: 5463560 Cursor Line No.: 5463477]

File Image display View ?

stopped 10 150.0%

Track information - RailView	
Division	IND
Line	6AVE
Track	B2
Location	822+80
Date	08/09/2010
File	277
Time	12:53:58
Speed	28,5 mph

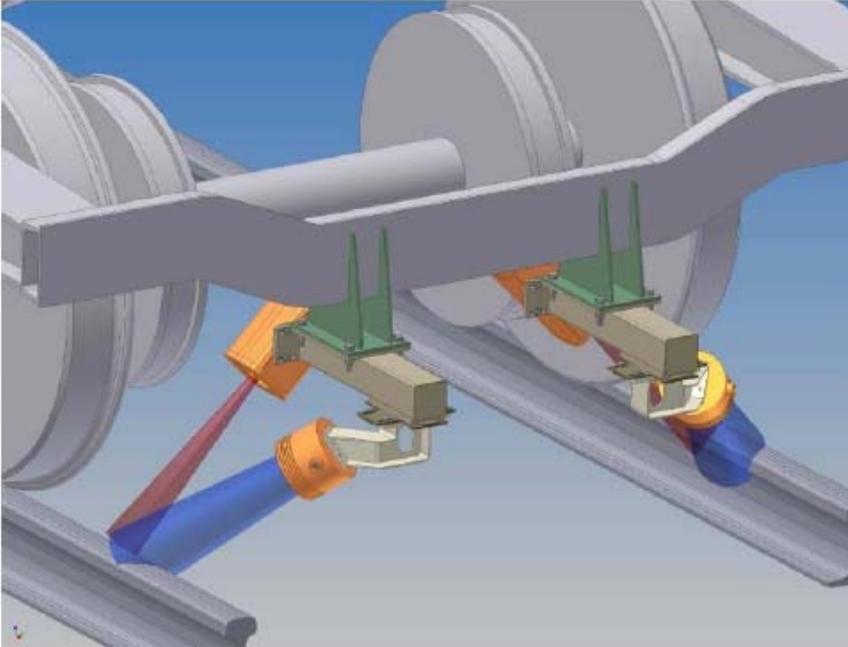
Record mode Sensor0: onboard Sensor1: onboard

NUM

Start In-box - Microsoft... Platform Gaps New initiatives f... Track Inspection... Telegrammanager DB-Manager ImageServer 1... 3 ImageViewer EventManager E... Search Desktop 2:00 PM



# Side View Video System



***Conceptual Layout of the Side View Video System's Cameras (orange, red beams) and Floodlights (orange, blue beams), attached to the truck frame of the Track Geometry Car***



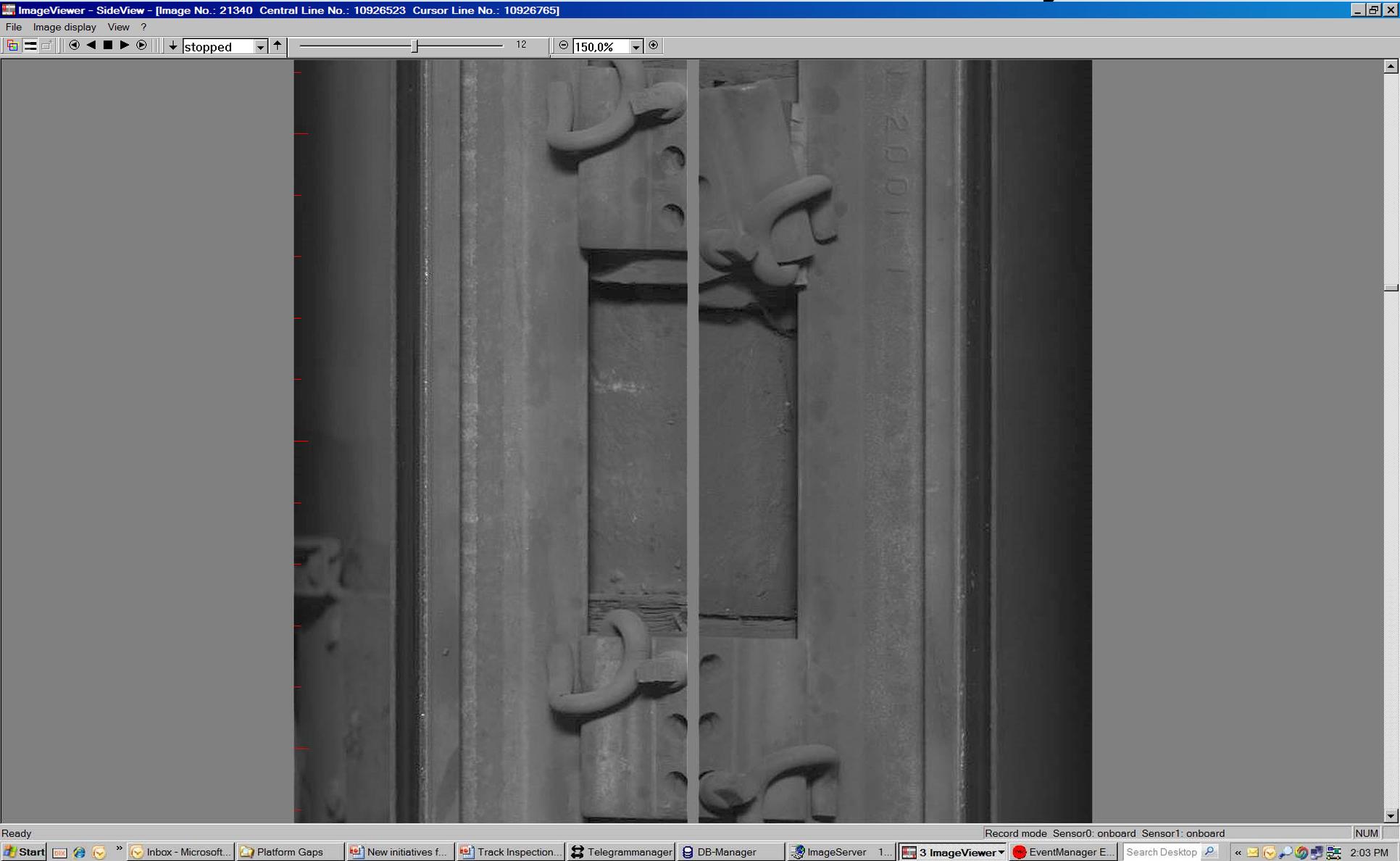
***Computer simulation of Side View camera looking at the rail gauge corner***

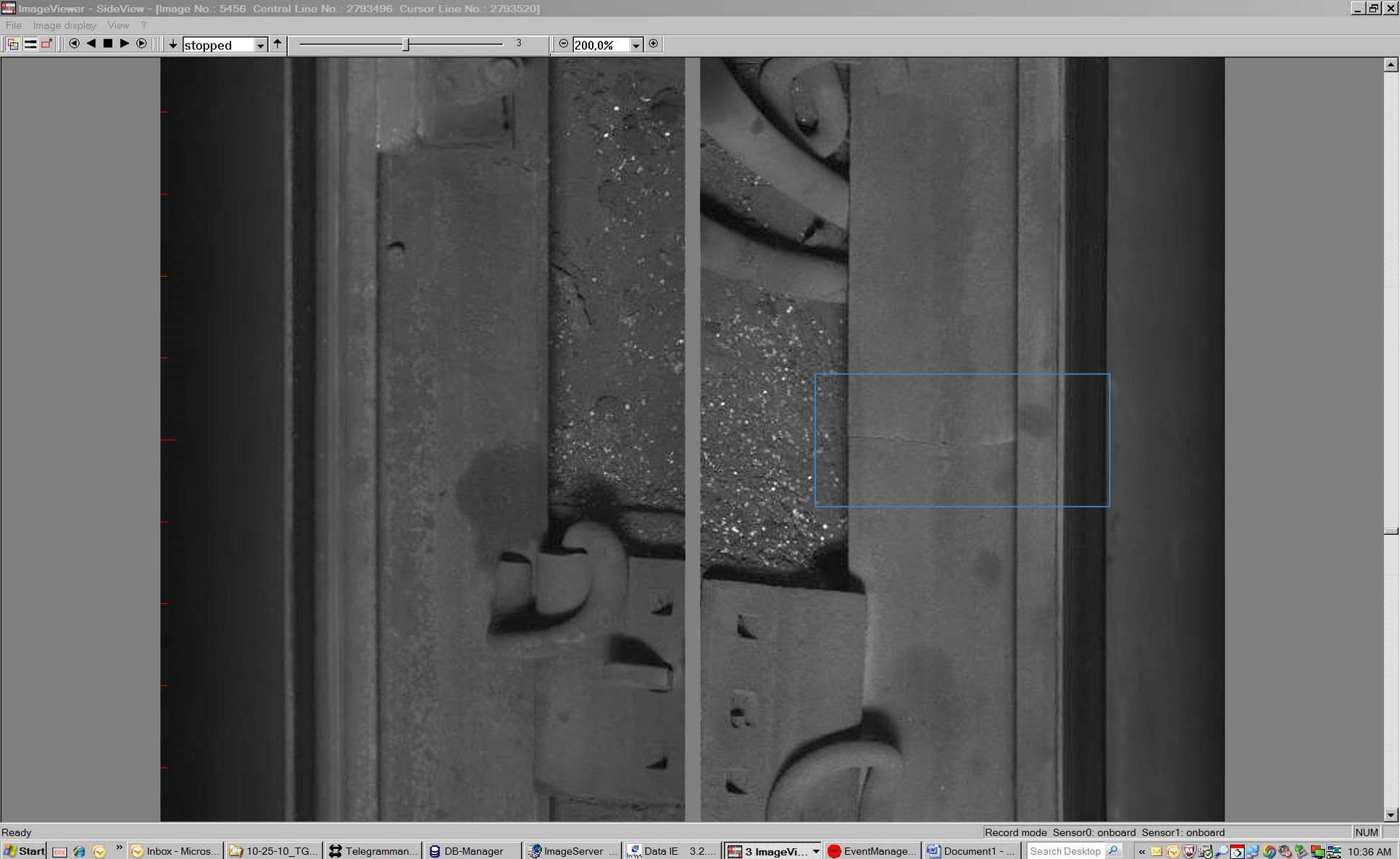


# 100% Zoom of the Side View Video systems



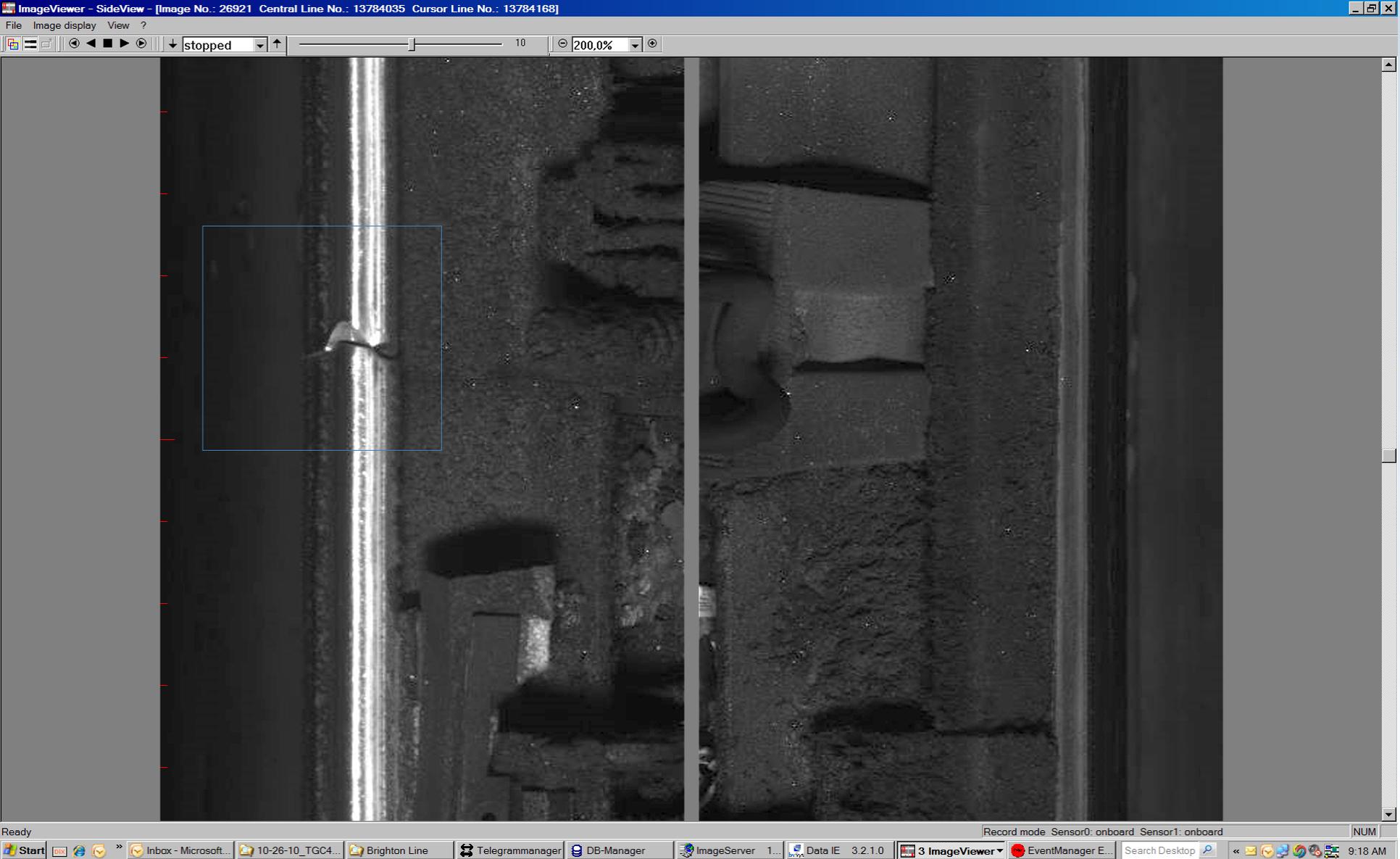
# 150% Zoom of the Side View Video systems





## Visible Cracked Rail





## Visible Broken Rail Head



# Right-of-Way, Side View and Rail View Video systems

The screenshot displays three separate ImageViewer windows, each showing a different perspective from a train's onboard camera system. The windows are titled 'RailScan FrontRear', 'SideView', and 'RaiView'.

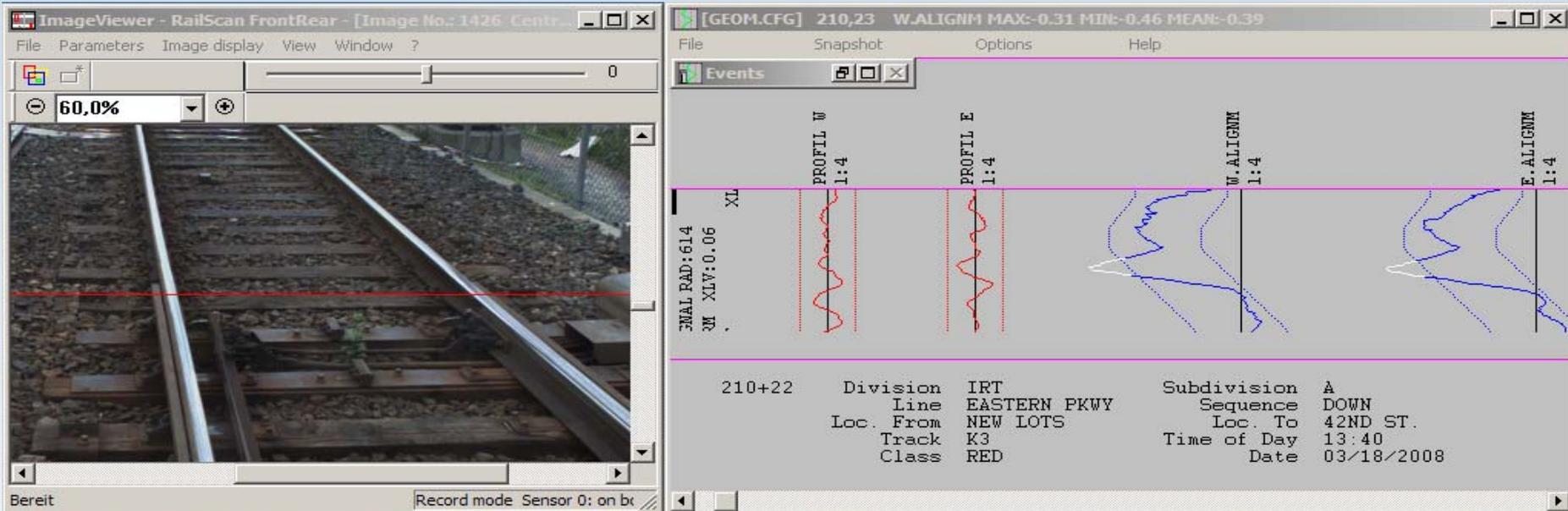
**Top Left Window: RailScan FrontRear**  
Title: Image No.: 2626 Central Line No.: 2710548  
Zoom: 50.0%  
Track information - RailScan:  
Division: IND  
Line: CULVER  
Track: B2  
Location: 716+35  
Date: 08/09/2010  
File: 277  
Time: 12:43:44  
Speed: 10.1 mph  
Status: Record mode Sensor0: onboard

**Top Right Window: SideView**  
Title: Image No.: 15413 Central Line No.: 7891638 Cursor Line No.: 7891475  
Zoom: 100.0%  
Status: Record mode Sensor0: onboard Sensor1: onboard

**Bottom Window: RaiView**  
Title: Image No.: 15415 Central Line No.: 3946298 Cursor Line No.: 3946074  
Zoom: 100.0%  
Track information - RaiView:  
Division: IND  
Line: CULVER  
Track: B2  
Location: 716+35  
Date: 08/09/2010  
File: 277  
Time: 12:43:44  
Speed: 10.1 mph  
Status: Record mode Sensor0: onboard Sensor1: onboard



# Right-of-Way, Geometry Chart and Rail View Video systems



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

- FTA Office of Research Project NY-26-7112 Granted to NYCT \$500 K on March 2012
- FTA Objectives:
  - Improve right-of-way safety of Track Inspectors through advanced track inspection techniques limiting the Inspectors' exposure on live tracks
  - Enhance the quality of the track inspections and reporting of defects
- Use of NYCT's TGC4, already equipped with Rail Top View, Gauge Side Rail View and Right-of-Way Video Systems, coupled with the other existing measuring systems, was found to be ideally positioned to accomplish the research objectives.
- Plasser American Corp. (manufacturer of the TGC4 and its measuring systems) agreed to be a partner to this Project.
- Project was performed in four Phases, starting in April 2012.



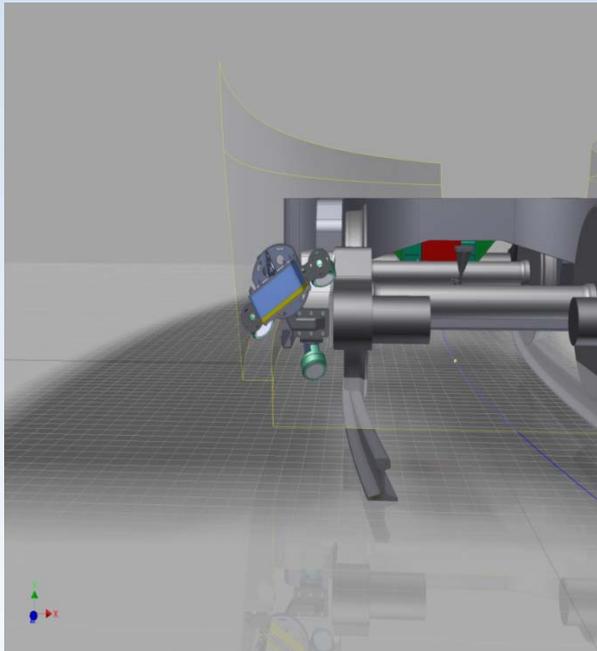
# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

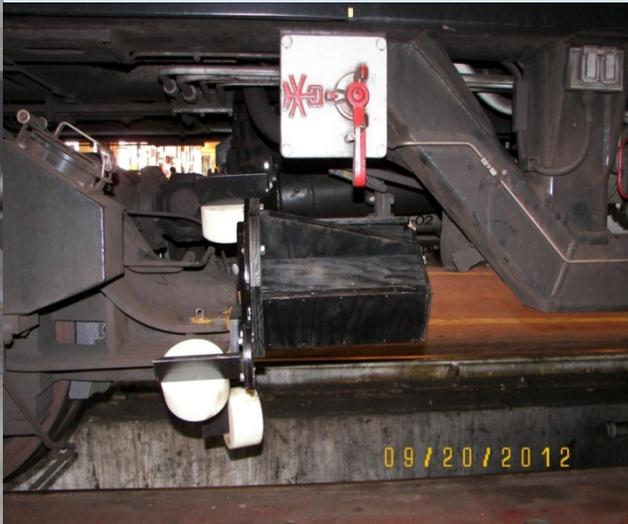
- **Phase 1:** perform an engineering and feasibility study to evaluate the possibility of installing a Power Rail (third rail) View video system and a Field Side Rail View (of one running rail) video system, using the existing Gauge Side Rail View video systems installed on the TGC4 as the research platform.
- Phase 1 performed by Plasser American Corp. (PAC) in May 2012, and successfully completed by September 2012.
- The feasibility study performed by PAC, with support of NYCT, confirmed that installation of a Power Rail View (of the 3<sup>rd</sup> rail on one side of the track) and a Field Side Rail View (of one running rail) video systems on the TGC4 was feasible, and that the systems would be able to produce sharp images with the desired content at the selected mounting locations.



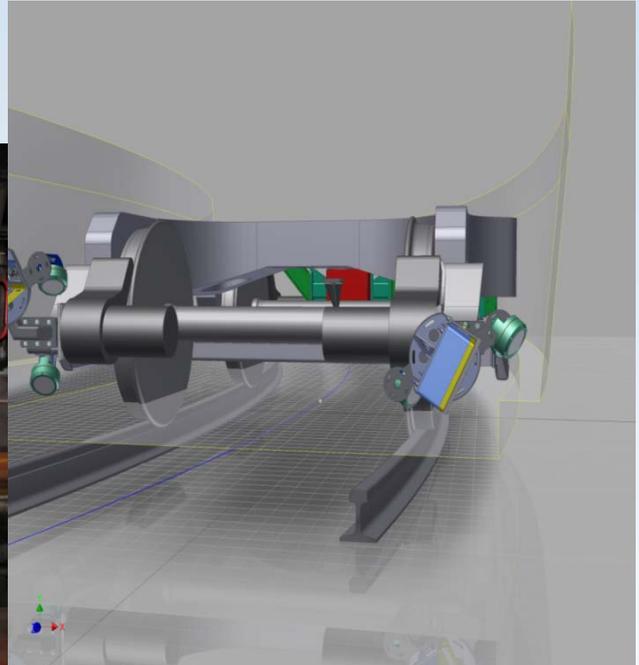
# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot



*Field side view clearance study in tight curve*



*Modified field side view video system mounting hardware with mock-up equipment installed*



*Power rail view clearance study in tight curve*

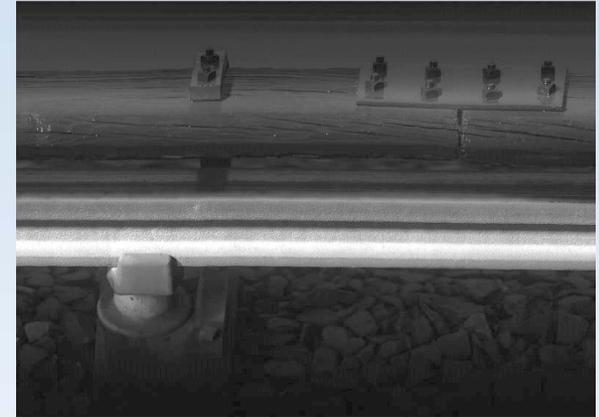
# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

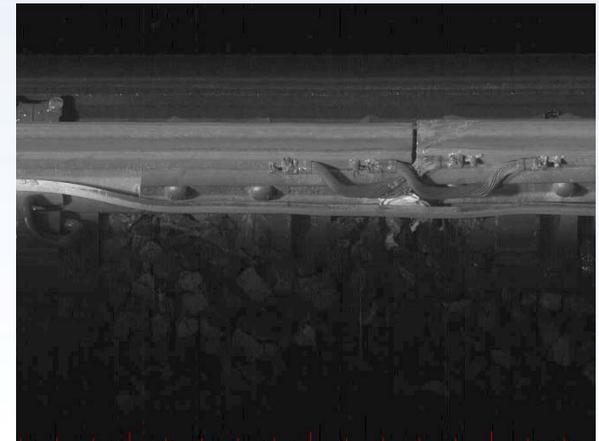
- **Phase 2:** work comprised the manufacturing and purchasing of the items necessary to install the cameras and the illumination equipment at the locations identified during Phase 1 of the project. The items produced and purchased for the installation included:
  - Mounting hardware for cameras and lights
  - Camera cables in sufficient length
  - Six halogen spot lights
  - Power supply for the halogen spot lights
  - Cables to power the spot lights
  - Circuit breakers for the lights
  - Miscellaneous material such as screws, cable ties, connectors, etc.
- The above items were successfully installed and tested at different NYCT's curved and tangent locations.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot



**Power Rail View Video System Installed and Picture Obtained**



**Field Side Rail View Video System Installed and Picture Obtained**



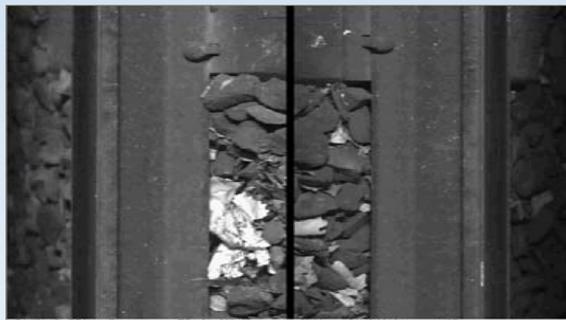
# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

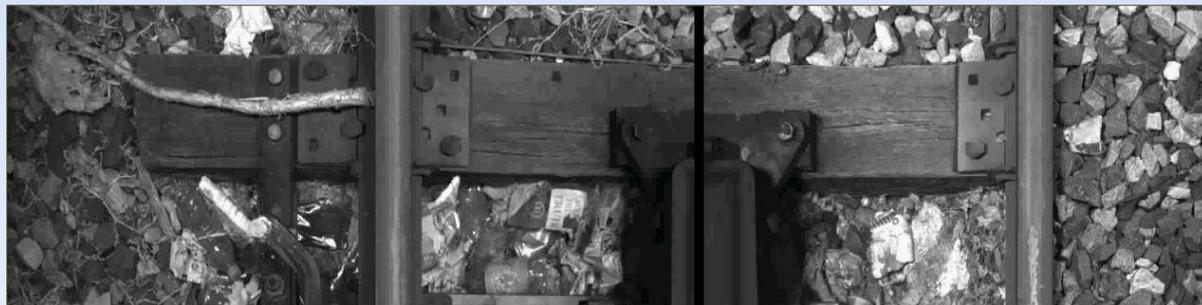
- **Phase 3:** implementation of the following additions to the existing video software:
  - Video Image File to AVI Conversion (for universal access)
  - Increase Field Size for User inserted Comments
  - Anomaly (Event) Marking Box Border Width
  - “Go To Location” Feature
  - Flangeway Measurements Display
  - Historical Anomaly (Event) Marking Box Import Feature
  - Playback of two runs simultaneously
  - Moving Reference Line
- The above additions were needed to export marked defects to subsequent runs of the same track, to playback two runs of the same track concurrently and to synchronize the Track Geometry chart printout with the video images collected.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

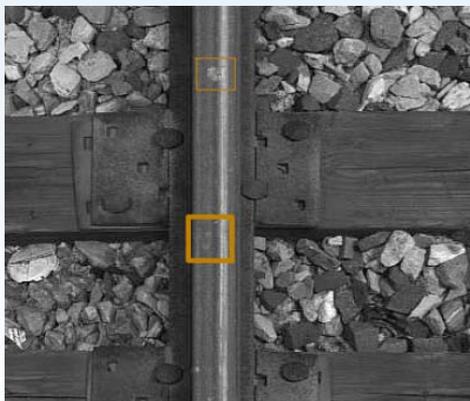


DIVIS SUBDI LINE TRACK 763+36 11.00.31 08/18/2010 105

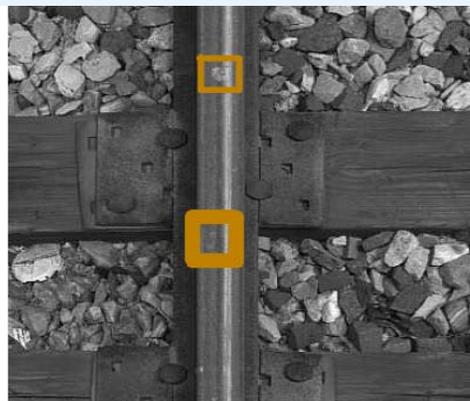


DIVIS SUBDI LINE TRACK 750+3 11.06.16 08/18/2010 1500

*AVI Video files of Field Side Rail and Rail View*



*Example with  
border width 1*



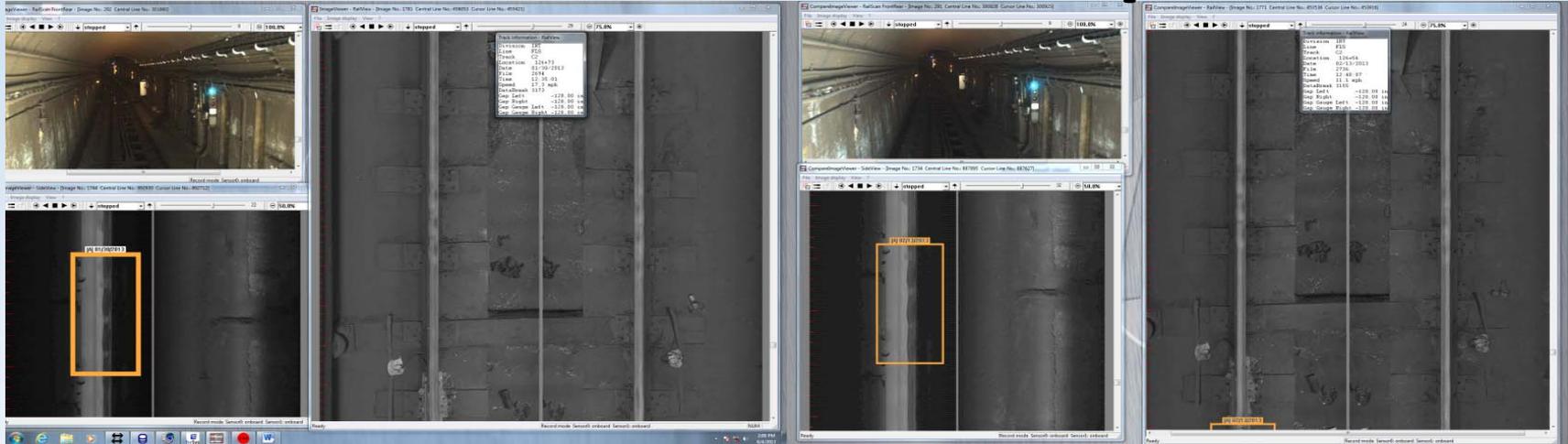
*Example with  
border width 5*



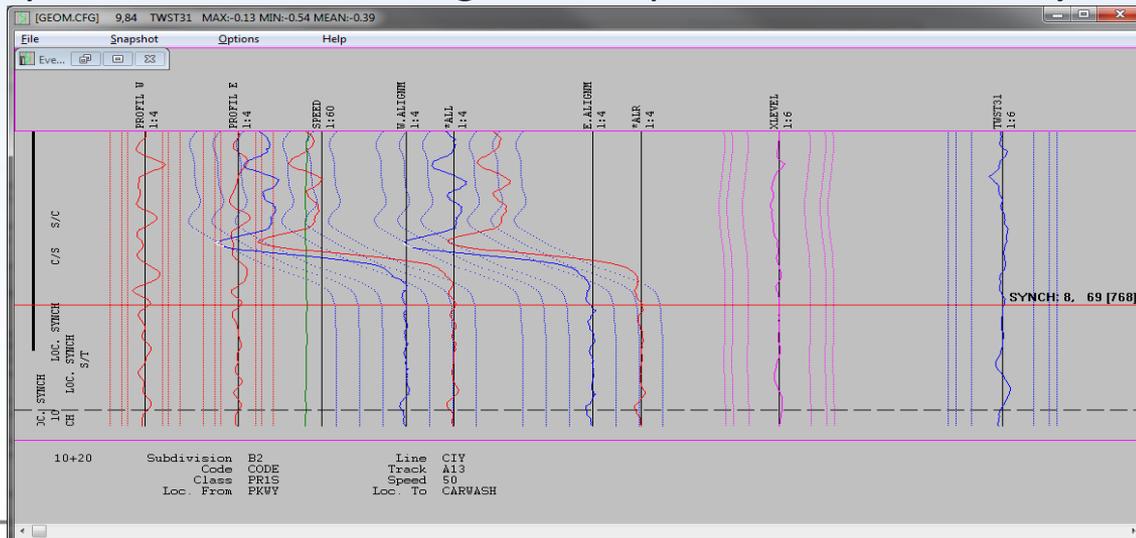
*Imported marking boxes  
(events) are shown with the  
date of the previous run*



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot



*Compare Viewer showing two inspection runs side by side*



*Track  
Geometry  
Printout  
with Synch  
Line (red  
line)*



[02-24-14Can Q1 P1 Dip.avi](#)



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

- **Phase 4:** perform a Pilot Inspection on a portion of the Flushing Line between Queensboro Plaza and Times Square Station with the TGC4:
  - The goal was to inspect both mainline tracks C1 and C2 of the portion of the Flushing Line to capture detailed images of all track and power rail (on one side only) elements and integrate them with the other existing measuring systems on the TGC4.
  - One (1) “debugging” run and three (3) test runs were performed using the installed video and measuring systems and the enhanced video software delivered under Phase 3.
  - The three test runs captured detailed video images of the track and power rail components (power rail on one side only) as well as track geometry, third rail, UT and tunnel measurements using all the video and measuring equipment on board the TGC4, under dynamic loads, at track speeds without problems.



# Demonstration of Machine Vision

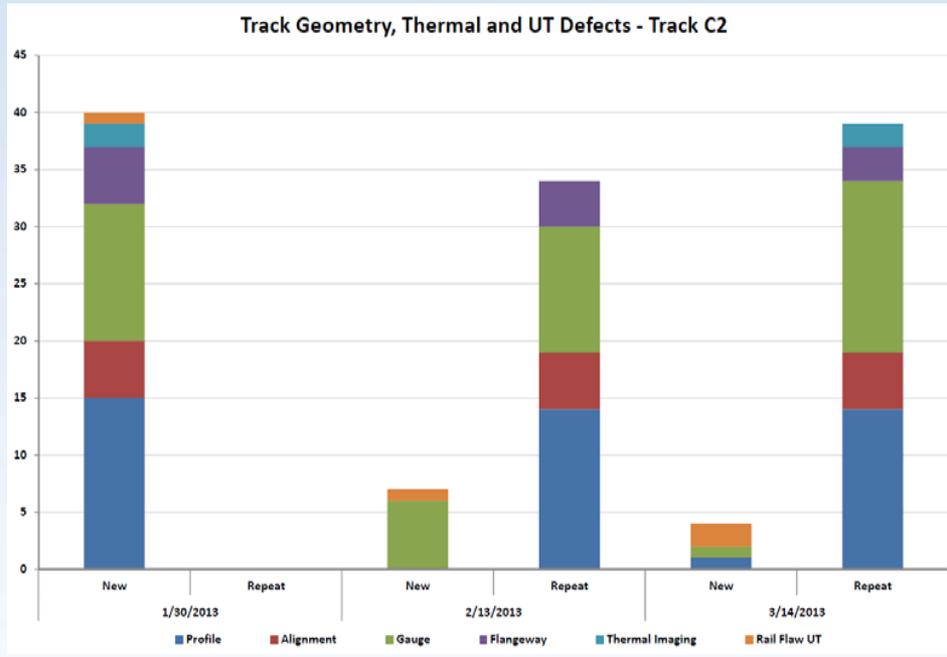
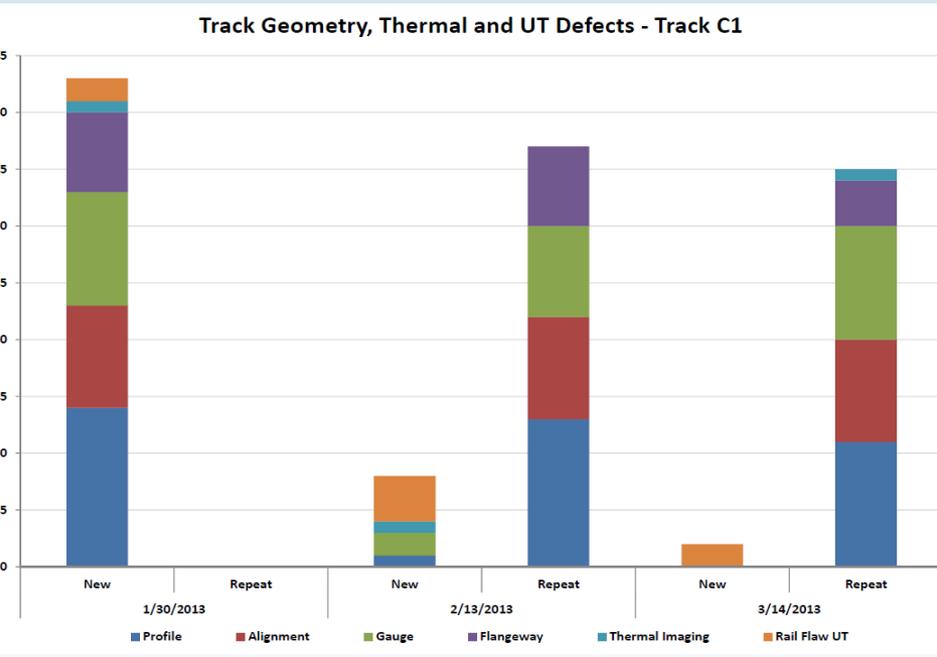
## Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- Defects or conditions detected by the TGC4's Video Systems **remain fairly constant for a period of at least 43 days** in tracks C1 and C2 of the Flushing Line between Times Square and Queensboro Plaza.
- The TGC4's **Video Systems can detect more detailed, accurate, and objective defects or conditions** than the Track Walkers can observe. The Video Systems detected **90** defects or conditions on track **C1** and **96** on track **C2** in the January 30, 2013 inspection alone.
- In comparison, the Track Walker Inspections found only similar **36** defects or conditions on track **C1** and **41** defects on track



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

COMPARISON OF TGC4 VIDEO DEFECTS WITH THE TRACK WALKER INSPECTION DEFECTS

FLUSHING LINE - TRACK C1 - TIMES SQUARE TO QUEENSBORO PLAZA

TGC VIDEO ANALYSIS					TRACKWALKER INSPECTIONS				POSSIBLE SAME CONDITIONS
Defects Found	Defects Found		Defects Found		TOTAL TRACK WALKER DEFECTS	TRACK WALKER DEFECTS DATED	TRACK WALKER DEFECTS DATED	TRACK WALKER DEFECTS DATED	TGC VIDEO/ TRACK WALKER COMMON TRACK CONDITIONS
1/30/2013	2/13/2013	Number Fixed	3/14/2013	Number Fixed	2011 - 2013	2011	2012	2013	
90	89	1	88	1	98	85	8	5	

COMPARISON OF TGC4 VIDEO DEFECTS WITH THE TRACK WALKER INSPECTION DEFECTS

FLUSHING LINE - TRACK C2 - TIMES SQUARE TO QUEENSBORO PLAZA

TGC VIDEO ANALYSIS					TRACKWALKER INSPECTIONS				POSSIBLE SAME CONDITIONS
Defects Found	Defects Found		Defects Found		TOTAL TRACK WALKER DEFECTS	TRACK WALKER DEFECTS DATED	TRACK WALKER DEFECTS DATED	TRACK WALKER DEFECTS DATED	TGC VIDEO/ TRACK WALKER COMMON TRACK CONDITIONS
1/30/2013	2/13/2013	Number Fixed	3/14/2013	Number Fixed	2011 - 2013	2011	2012	2013	
96	96	0	95	1	128	103	11	14	



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- Visual track inspection reports produced by NYCT's Track Walkers can not be compared properly with the TGC4 Video System defect reports:
  - Track Walker defect reports suffer from lack of clarity and objectivity, as there is no visual record that can be contrasted to assess the validity of the Track Walker's observations in detail;
  - Track Walker's Visual Inspection Database suffer from ambiguity regarding the description and magnitude of the defects;
  - Track Walker defects are not updated and purged from the database as they are corrected, or reinspected.
- Many of the Track Walker's visual defects could therefore not be verified using the TGC4's Video Systems.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- TGC4 Video Systems provide the means to analyze defects at any time by different reviewers, confirming defects almost instantly, providing a more objective and accurate report to maintenance personnel, eliminating any subjectivity.
- The TGC4 Video Systems can serve as to complement the measurements acquired with the other measuring systems, providing images of the defect location to maintenance crews.
- In addition, the TGC4 Video Systems make the reports detailed, accurate and informative of the track conditions and measurements found.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- The Compare Viewer software plays back and transfers the marked defects from one video inspection run to the next, without the need for a lengthy review process.
- Once the initial files on the TGC4's Rail View, Field Side Rail View or Power Rail View Video Systems have been analyzed and marked with the defects or conditions found, these can be transferred easily and accurately to future video inspection files, expediting the analysis of defects found.



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- Marking of video defects on the initial or base inspection run is essential to save reviewing time in future video inspection runs.
- A key factor, at the present time, for any successful, accurate and quality video inspection is the experience, dedication, accuracy and track knowledge of the personnel performing the video review.
- The reviewer assigned to analyze, review and mark the defects and log them into a database must be willing to dedicate long hours to review the video files with accuracy and keen attention.



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- Track Walker inspection of the subway portion between Times Square and Hunters Point Stations:
  - is performed by a team composed of one Flagger and one Track Walker, except for the Steinway Tube portion, which requires a General Order and an additional two Track Workers to set up trips and lights;
  - the team inspects track C1 on Wednesdays and Fridays and track C2 on Tuesdays and Thursdays. Thus, a total of 4 persons are able to inspect 12,000 ft. of track per night, in a 6-hour time period.
- Track Walker inspection of the elevated portion of the Line between Hunters Point and Queensboro Plaza Stations:
  - a team composed of a Flagger and a Track Walker are able to inspect each track, approximately 5,000 ft. long, twice a week, during a 2 to 3-hour time period.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- The TGC4 was able to **fully inspect each track and take all track measurements under dynamic loads:**
  - in less than 15 minutes each,
  - without exposing personnel to safety hazards,
  - without requiring the tracks to be taken out of service and,
  - at the same time providing for a more accurate, complete and objective inspection.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- **Track Video Inspection Systems could greatly improve Track Walker safety** because no personnel are needed to be on the tracks to perform the track inspections, and maintenance crews are aware of the areas where repairs need to be performed, in advance of their field work.
- The identification of critical defects, the prioritization of corrective repairs, the deployment of maintenance personnel for defect repairs, and the execution of maintenance and repairs could be optimized by the **use of the TGC4 Video Systems by Supervisors and Superintendents.**



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- Vehicle-Based Automated Video Track Inspection Systems, as envisioned, are indeed successful in augmenting the capabilities of detecting and confirming defects found by the TGC4's measuring systems.
- These video systems have the potential to provide a more detailed and comprehensive picture of the actual location where the defect can be found.



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- The TGC4's second and third (final) Video System runs found the same amount of track defects or conditions that were found on the first inspection run 43 days before.
- The conclusion is that a once-a-month Video Inspection, complemented with the analysis of all the other measuring systems on board the TGC4, has the potential to detect most of the priority defects or conditions on this segment of the Flushing Line.



# Demonstration of Machine Vision

## Assisted Automated Track Inspection Pilot

- **FINDINGS:**

- Several of the shortcomings observed with the Field Side Rail View and Power Rail View Video Systems were due to the fact that due to clearance constraints and lack of available space the existing cameras could not be installed close to the same truck.
- The Power Rail View Video System camera and illumination should ideally be placed in a lower position to allow viewing of conditions under the Cover Board.
- The illumination and quality of the Power Rail View Video system would need to be improved in order to detect certain cover board conditions such as shoe-rubbing marks.



# Automated Visual Track Inspections - Summary

- **Inspection from vehicle (TGC4)**
- **Assure safety of track inspectors**
- **High-speed video cameras with good lighting provide for higher quality inspections**
- **Permanent objective record of inspection**
- **Defects found can be correlated with geometry or other defects**
- **No degradation of on-time train performance**



# Demonstration of Machine Vision Assisted Automated Track Inspection Pilot

- **FURTHER RESEARCH:**

- The existing software is not capable of detecting rail, fastener and track condition defects automatically. However, automatic detection video inspection software does exist.
- It could be used in conjunction with the Rail View and Gauge Side Rail View Video Systems that the TGC4 already has to investigate if the software can automatically detect cracks in the side of the web or base of the rail, as well as base corrosion and wheel burns or “squats” on the top of the rail.
- All of them are critical defects that could cause broken rails in service. Therefore automatically detecting these issues could lead to a prompt removal or remediation of those conditions, therefore enhancing the safety of the tracks.

