Augmented Reality Technology for Design and Construction

Brad Hollister — Stantec

Dylan Jones — Frontier Precision

Matt Schwartz — BuildingPoint™

What does every AR/MR usage type have in common?

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The Model

The representation of an idea, a concept, a phenomenon, a thing

There are mathematical models, geometric models, process models, physical models

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Intro Agenda

The Model

Why Adopt a Model-Based Approach to Project Delivery?

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BIM Model

Building Information Model

Geometric Model – developed to accuracy and precision tolerances

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BIM Model Types

Operational Assets

Drainage Analysis

Design Coordination

Estimate

Geometric Design

Visualization AR/MR

Clash Detection

Traffic Analysis

4D/5D Project Management

As-Built

Maintenance Assets and Condition

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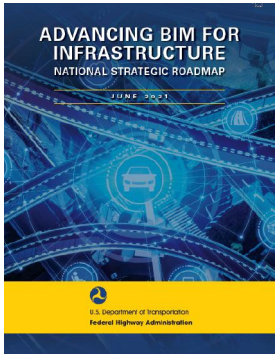
BIM Processes

AR/MR are one type of BIM use

BIM Processes Span the full facility lifecycle



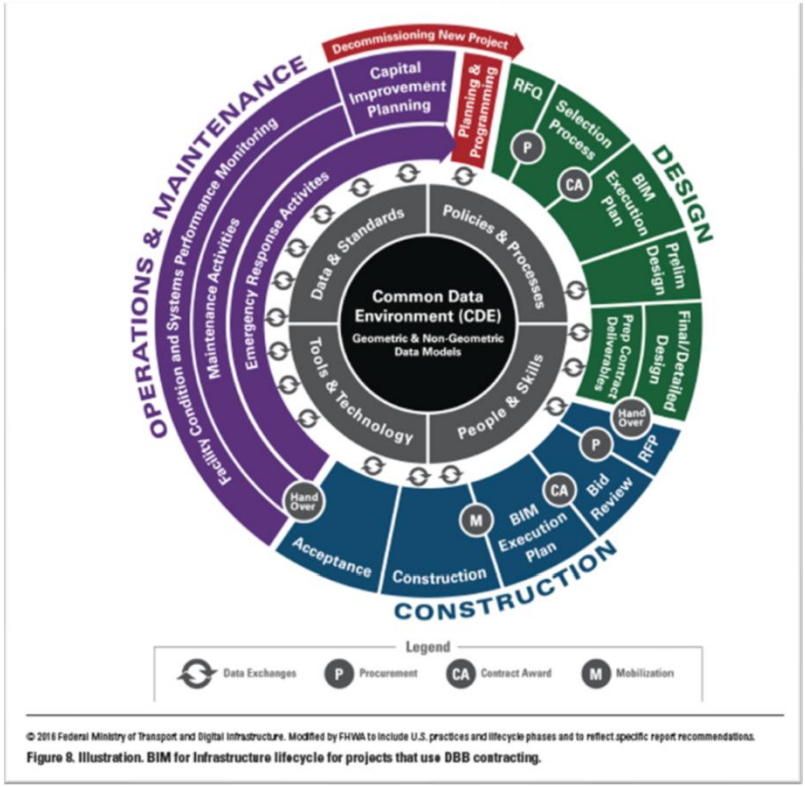


IMAGE SOURCE: [FHWA's Advancing BIM for Infrastructure National Strategic Road Map]

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BIM for Project Delivery

AR/MR are one type of BIM use

BIM has many applications within Project Delivery

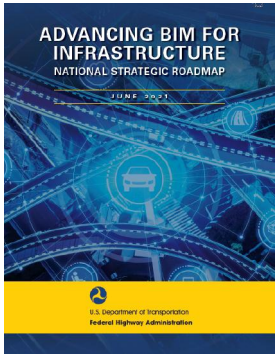

Table 2. Sample starter list of BIM for Infrastructure use cases.

Data-Exchange Opportunities	Use Cases From Within the Asset Lifecycle Phases That Would Benefit From BIM for Infrastructure Implementation
Planning to design	• Use planning and project data for design (e.g., location, design speed, traffic count)
Survey to design	• Collect preconstruction survey data
Survey to construction	• Track progress of construction through periodic surveys
Geotechnical to design	• Use geotechnical investigations for road design (e.g., road dimensioning, limiting deformation, ensuring road stability) • Conduct earthwork design using geotechnical data
Design to geotechnical	• Facilitate geotechnical construction by analyzing ground reinforcement and preloading sheet piling using design data
Design to design*	• Create 3D design as a technical visualization for public information • Estimate quantities or quantity takeoffs • Conduct a structural analysis, including the code compliance of parametric design • Conduct design reviews (interdisciplinary coordination/clash detection)* • Develop a detailed design using the early-design model
Design to construction*	• Create 3D design as a technical visualization for conflict and clash detection* • Create 3D design as a technical visualization for work-zone review and management • Use design data for bid-package preparation and construction (quantity take offs and AMG-related data)* • Draft prefinal and final plans with model as a contract document* • Develop four-dimensional (4D) scheduling (i.e., construction simulation and activity sequence modeling) • Develop earthwork cut and fill design for incorporating designed structure into the existing ground • Determine construction inspection and payment conditions, including inspection verification (compare as-built to as-planned assets) and acceptance*
Construction to construction	• Track construction progress • Measure quantities for payment • Conduct construction planning using geotechnical data, including safety reviews
Construction to asset management*	• Collect as-built data for assets (e.g., structures, pavements, safety appurtenances, road geometry, signs and striping, drainage and hydraulics and culverts), particularly for underground utility assets*
Design to asset management	• Determine asset inspection, condition forecast, and roadmap-related attributes • Transfer data associated with asset design to GIS and asset management systems
Asset management to design	• Model initial state using existing asset data
Asset management to planning	• Propose projects for authorization and programming

*High-priority use cases for BIM deployment.

Table SOURCE: [FHWA's Advancing BIM for Infrastructure National Strategic Road Map]

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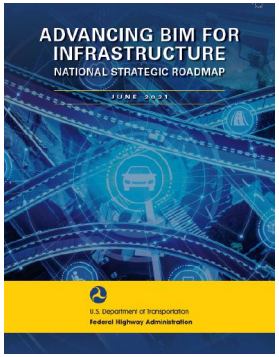
BIM and Digital Project Delivery

Why Use BIM in Project Delivery?



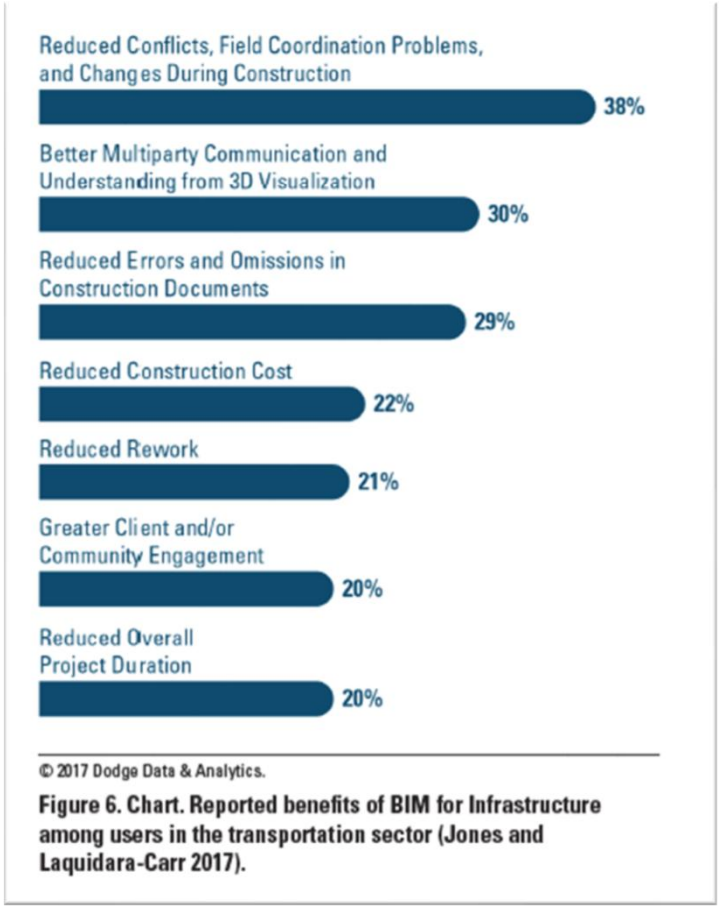


Figure 6. Chart. Reported benefits of BIM for Infrastructure among users in the transportation sector (Jones and Laquidara-Carr 2017).

CHART SOURCE: [FHWA's Advancing BIM for Infrastructure National Strategic Road Map]

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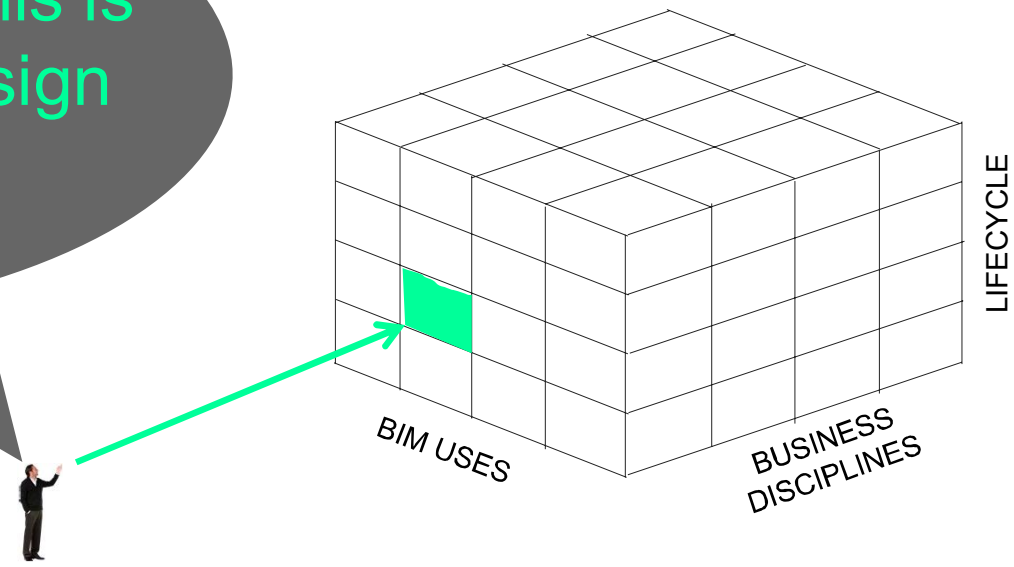
How do we get started?

"…and this piece here, this is our 3D Model-Based Design Implementation"

An organization's BIM Transformation is comprised of many implementations of various size and complexity



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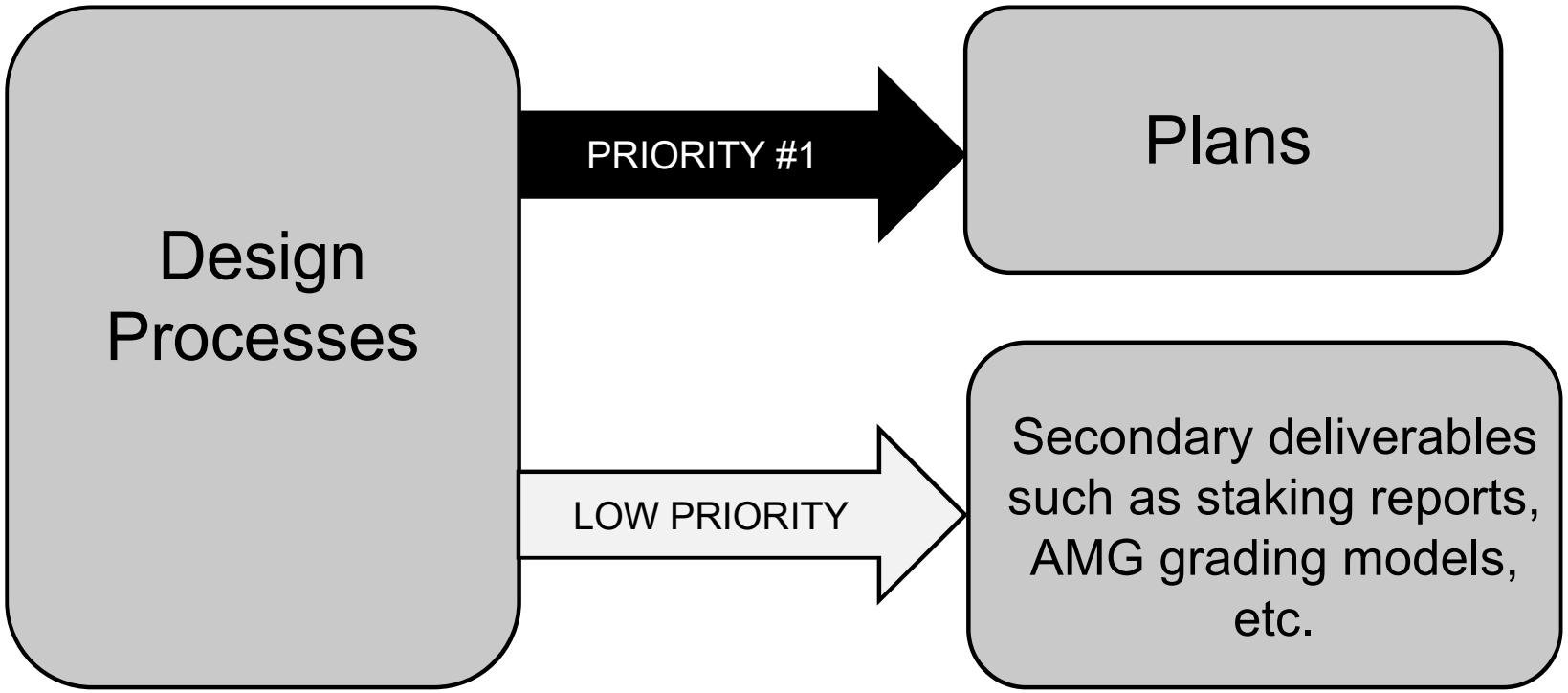
OLD SCHOOL DESIGN



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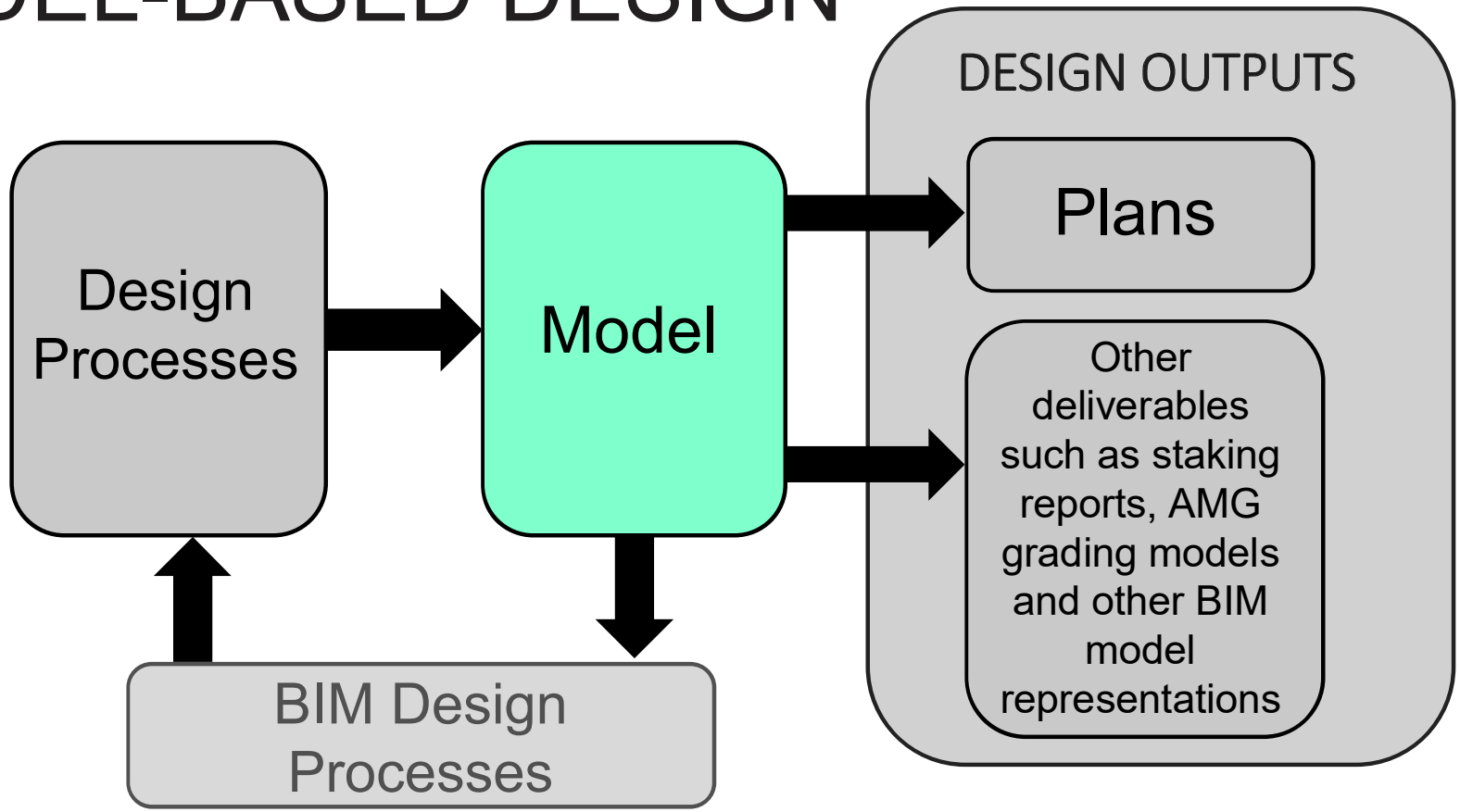
MODEL-BASED DESIGN



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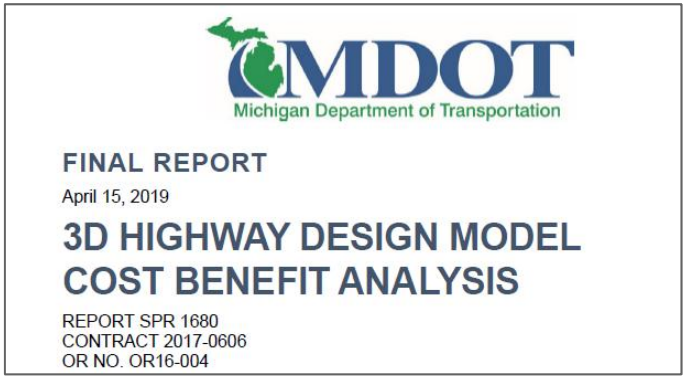
Michigan DOT 3D Highway Design Model Cost Benefit Analysis*

Studied Projects from 2012 to 2016

65 projects with traditional 2D + 3D RID deliverables

192 projects with traditional 2D delivery only



*https://www.michigan.gov/documents/mdot/2019-SPR-1680_652496_7.pdf

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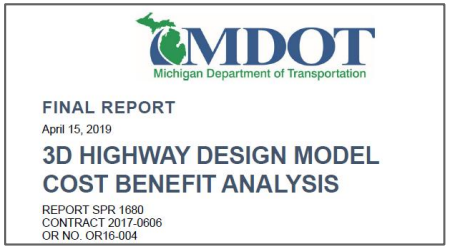
Michigan DOT 3D Highway Design Model Cost Benefit Analysis*



Executive Summary, Page 1:

"The historical data statistical analysis revealed that project sizes of $5 million to $20 million benefit the most from the use of 3D models. However, **3D models (indiscriminate of project size) consistently produced bids that were lower than the engineer's estimate. When bids came in higher than the engineer's estimate, 3D models produced fewer change orders than 2D plans."**

*https://www.michigan.gov/documents/mdot/2019-SPR-1680_652496_7.pdf

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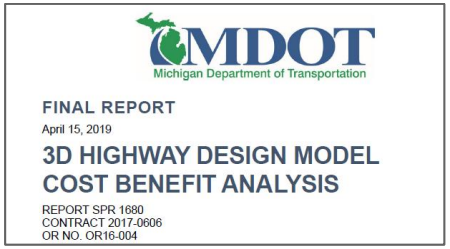
Table 21. Summary of calculations for the 5-year ROI of MDOT's implementation of RID 3D models.

Value	Output ($)
Average Construction Program ($)	$ 1,249,400,000
Timeframe	5 Years
Cost Over Timeframe ($)	$ 56,752,963
Benefits Over Timeframe ($)	$ 74,964,000
Net Benefits	$ 18,211,037
5-Year ROI (%)	32.03%
Breakeven Year	Year 1



*https://www.michigan.gov/documents/mdot/2019-SPR-1680_652496_7.pdf

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Bid Cost Effects

$$\text{Award Growth} = \frac{\text{Awarded Contract Value} - \text{Engineer's Estimate}}{\text{Engineer's Estimate}} \; x\ 100$$

Equation 1. Formula for calculating award growth parameter.

Table 8. Historical data award growth analysis summary (for all regions).

Award growth – All Regions	2D Plans	3D Models
Count	192	65
Average	+3.0%	-1.4%
Standard Deviation	15%	15%

Net 4.4% Change

MDOT Michigan Department of Transportation

FINAL REPORT

April 15, 2019

3D HIGHWAY DESIGN MODEL COST BENEFIT ANALYSIS

REPORT SPR 1680
CONTRACT 2017-0606
OR NO. OR16-004

*https://www.michigan.gov/documents/mdot/2019-SPR-1680_652496_7.pdf

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Project Level Savings

2D Traditional	2D + 3D
Estimated Construction Cost	
$1,000,000	**$1,000,000**
Typical Design Cost (9% of Estimated Cost)	(+10% for 3D)
$90,000	**$99,000**
Bid Results (Estimated Cost + 3%)	(Estimated Cost - 1.4%)
$1,030,000	**$986,000**
(Design + Construction) Delivery Cost	
$1,120,000	**$1,085,000**
Delivery Cost Savings	
($1,120,000 - $1,085,000) = **$35,000**	

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Project Level Savings

$35,000

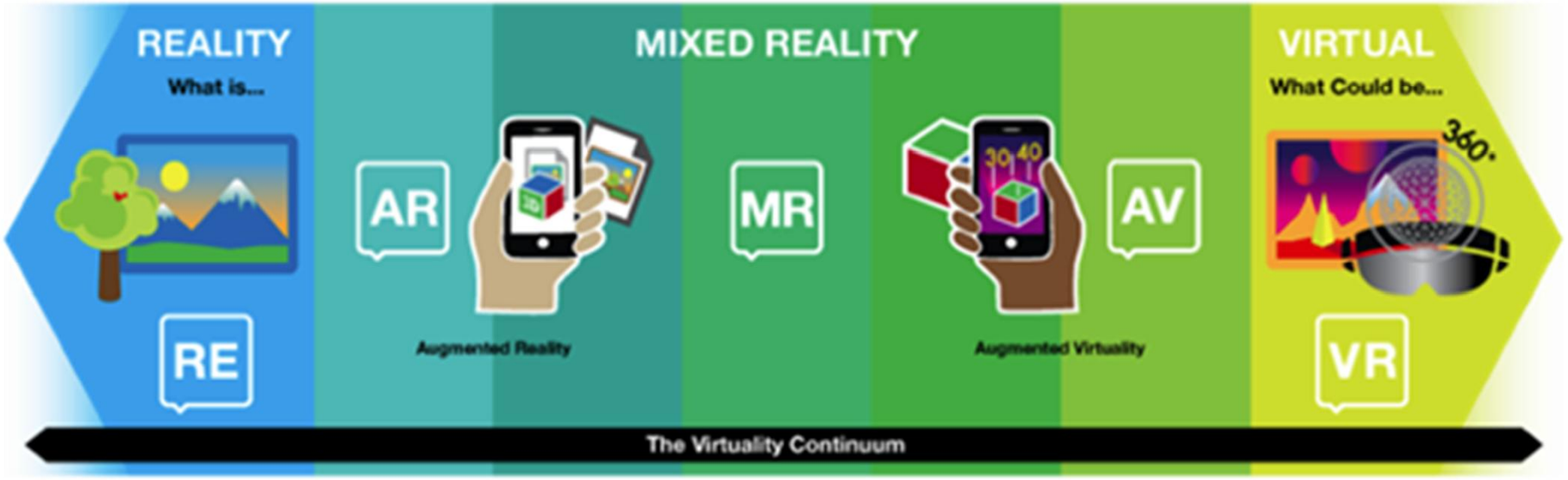
Project Delivery Cost Savings equals

39% of Design Effort

($35,000/$90,000)

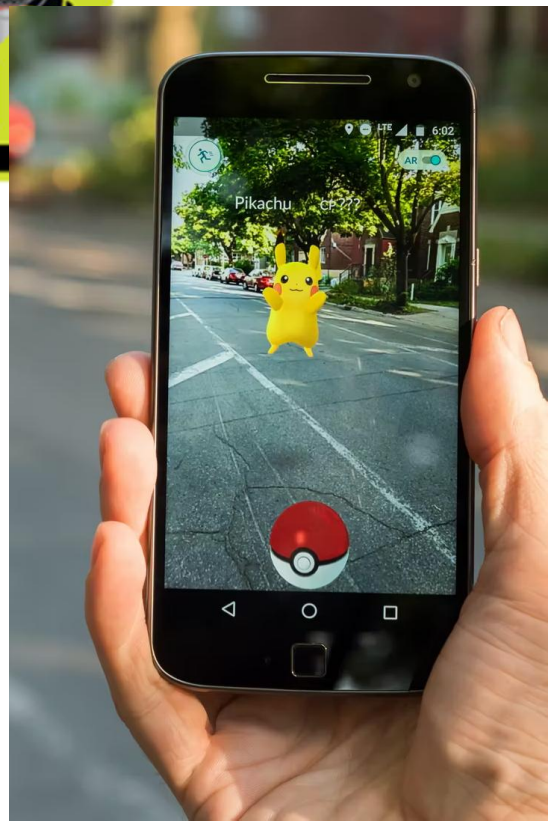
What is AR | MR | VR?

The Virtuality Continuum

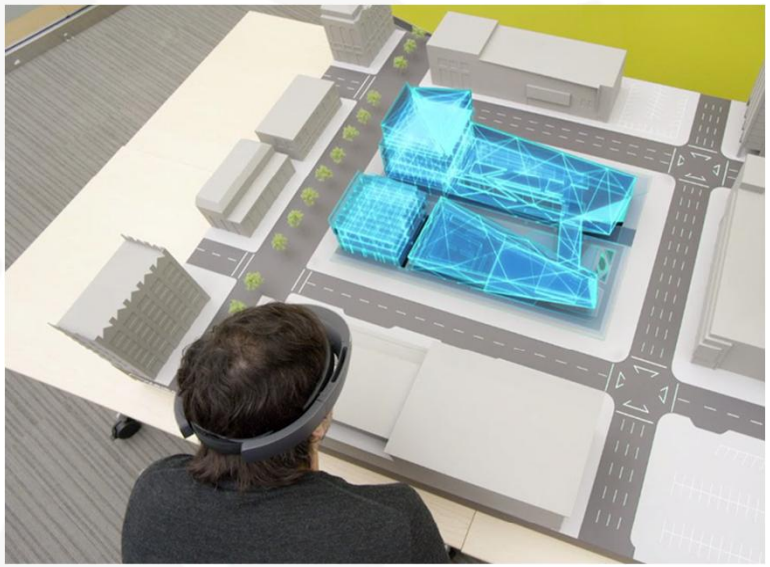


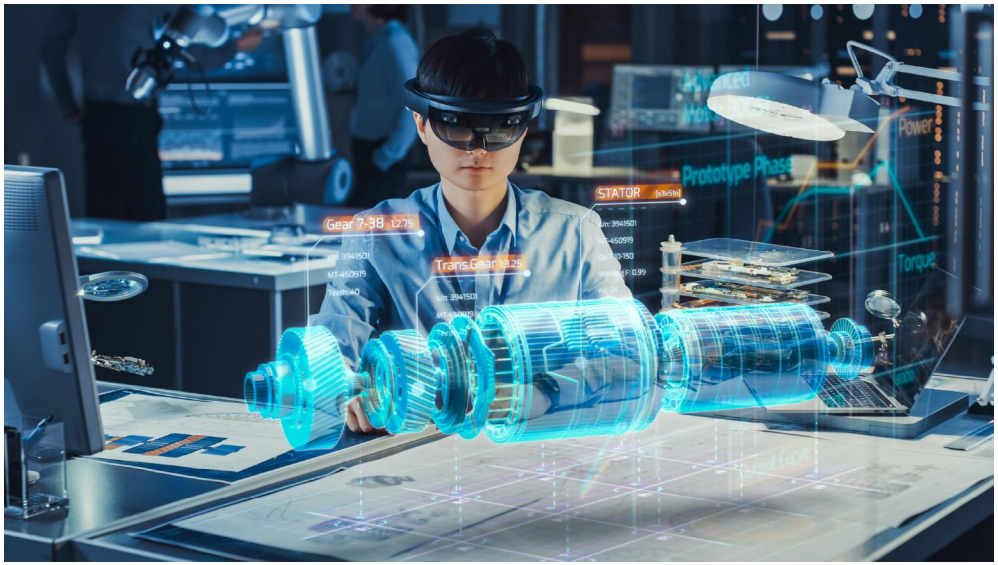
The Virtuality Continuum

The Virtuality Continuum



The Virtuality Continuum





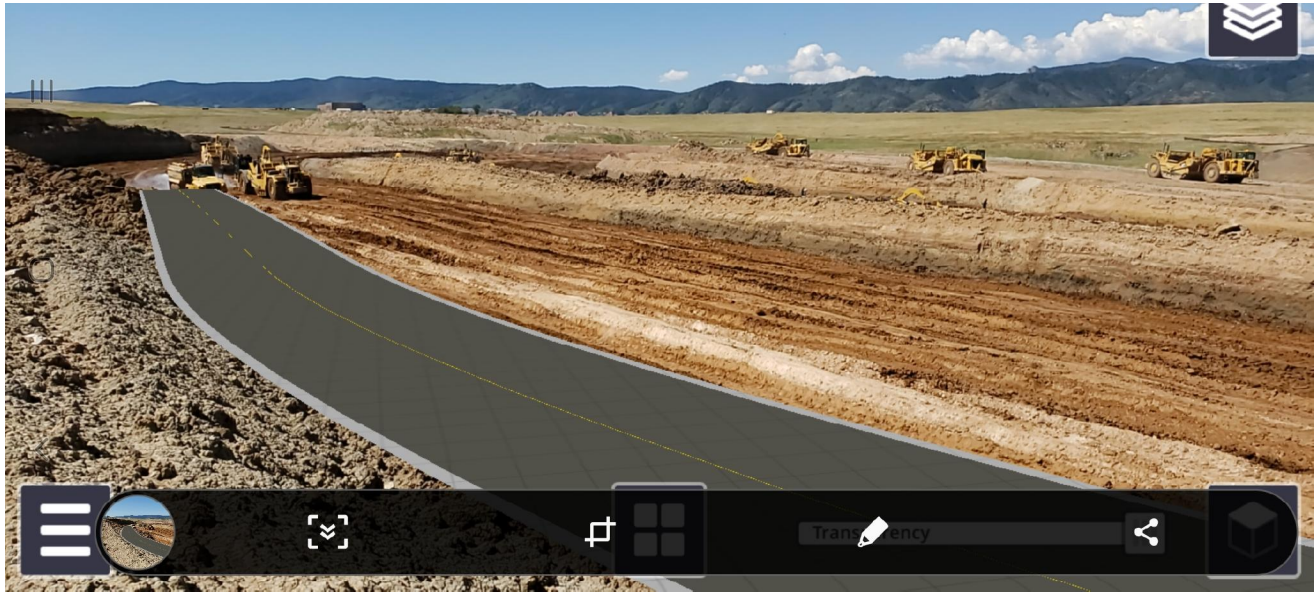
The Virtuality Continuum

The use of Mixed Reality in the field brings a couple of challenges:

- How do we display the model?
  - Smaller devices needed to have the power to display complex models
  - Device developers needed to have platforms available – ARCore
- How do we accurately position the model in the field?
  - There is a need accurate positioning and accurate heading/orientation.

Trimble | SiteVision

- **Visualize:** High accuracy data in context, for use outdoors
- **Collaborate:** Interact with data and share with stakeholders
- **Report:** Capture meaningful observations for editing and verifying data



How it works…

This technology is already in the hands of surveyors

Positioning + Orientation => Models fall into place in outdoor environments

Insert video:
As the camera moves, the position and orientation of the system is updated immediately. The updated position and orientation then update the model overlay placement on the image.

Mixed Reality for the geospatial segment targets, but is not limited to, four main workflows:

- Underground infrastructure: **See the hidden**
- Above ground structures: **See the future**
- On-ground surfaces: **See the progress**
- In-ground line work: **See the boundaries**

Site Control Verification and Plans

Visualizing survey points and PDF plans

Site Control Verification and Plans

Visualizing survey points and PDF plans

Underground Infrastructure

Visualizing Underground Infrastructure:

- Water
- Power
- Gas
- Telecommunications

- Improves crew site understanding and safety
- Reduced interruptions
- Design vs. As-Built clash detection
- Asset attributes accessibility

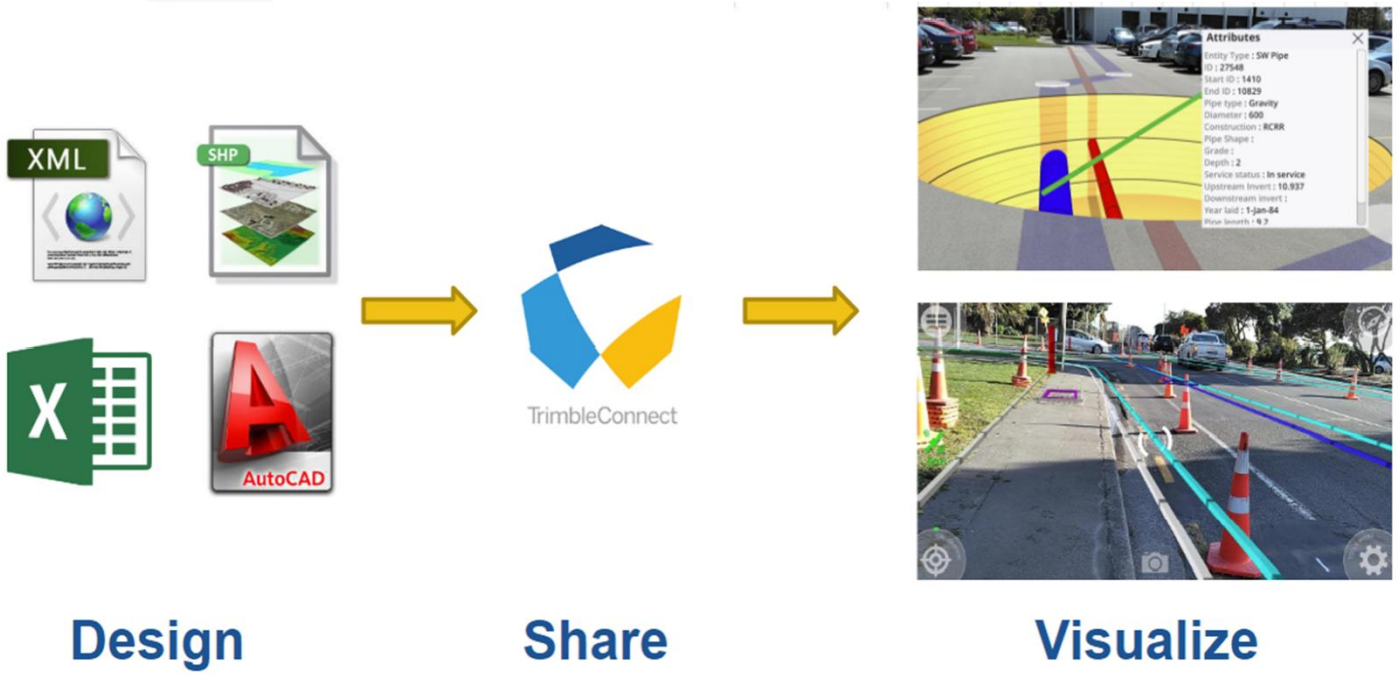
Utility Verification

GNSS Measurement

EDM Measurement

Underground Infrastructure

Infrastructure Formats: SHP, XML, IFC, CSV, DXF, DWG, VCE



Above Ground Structures

Visualizing Above-Ground Structures:

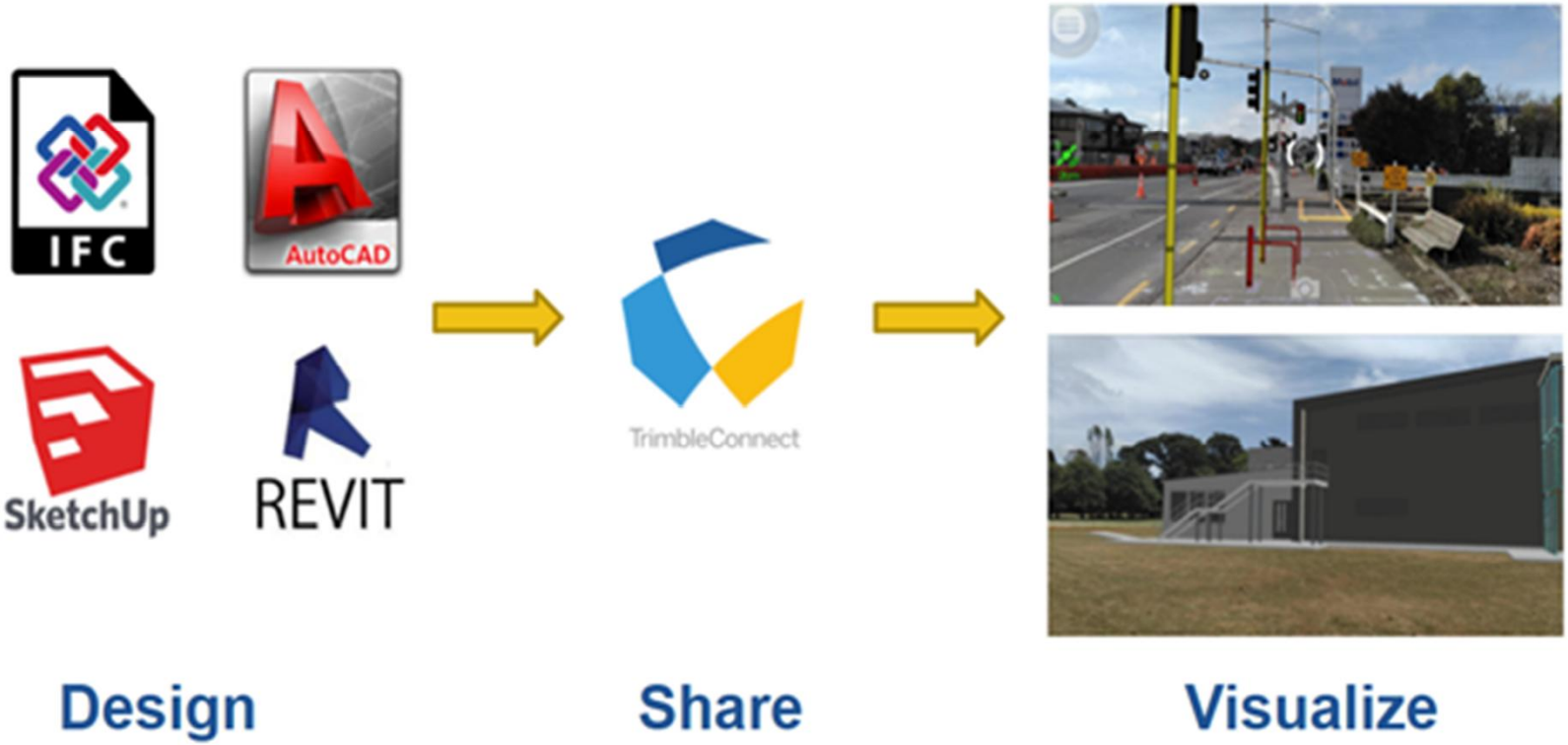
- Roadways
- Intersections
- Buildings
- Bridges

- Fully rendered 3D models
- Client project sign-off
- As-built QC
- Design phase verification

Building Visualization

Above Ground Structures

Structures Formats: IFC, DWG, DXF, SKP, RVT

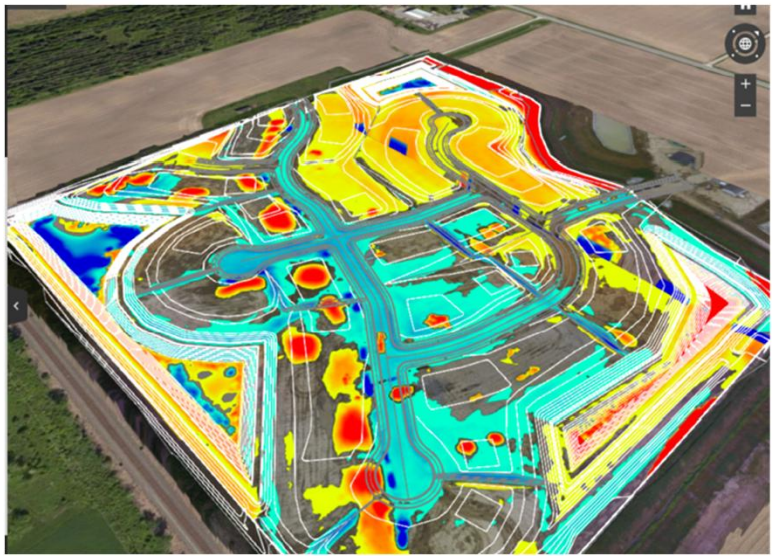


Earthworks and Surfaces

<u>Visualizing On-Ground Surfaces</u>:

- Design surfaces
- Graded surfaces
- Cut/fill height values

- Visualize a stake-less site
- Coordinate earth moving work
- Check project progress



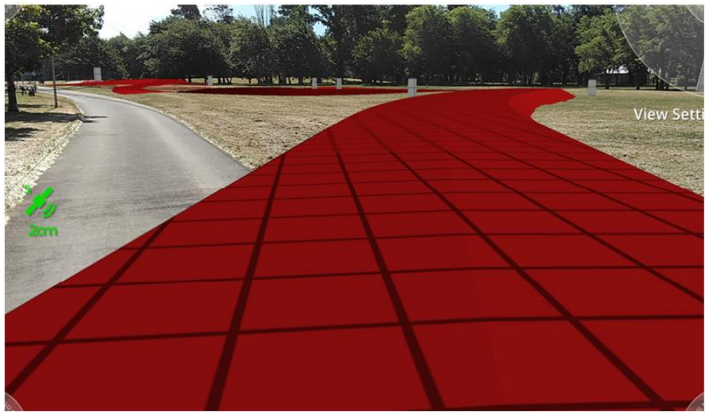
Grading Verification

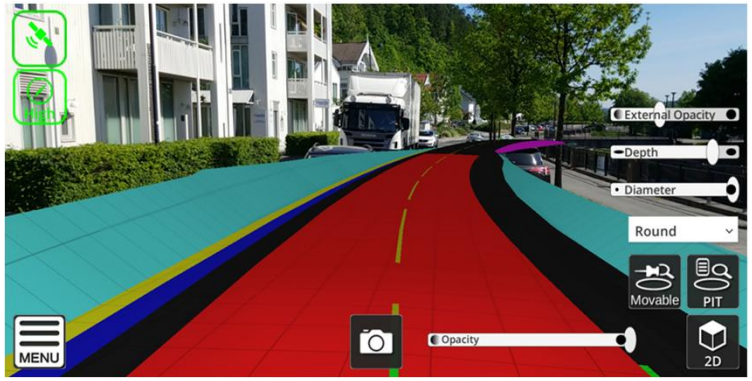
GNSS Measurement

EDM Measurement

Earthworks and Surfaces

Surfaces Formats: SKP, XML, DXF, VCE





Boundaries

<u>Visualizing In-Ground Line Work</u>:

- Cadastral boundaries
- Property ownership information
- Site exclusion zones

- Property management
- Vegetation management
- Client communication
- Improved site safety

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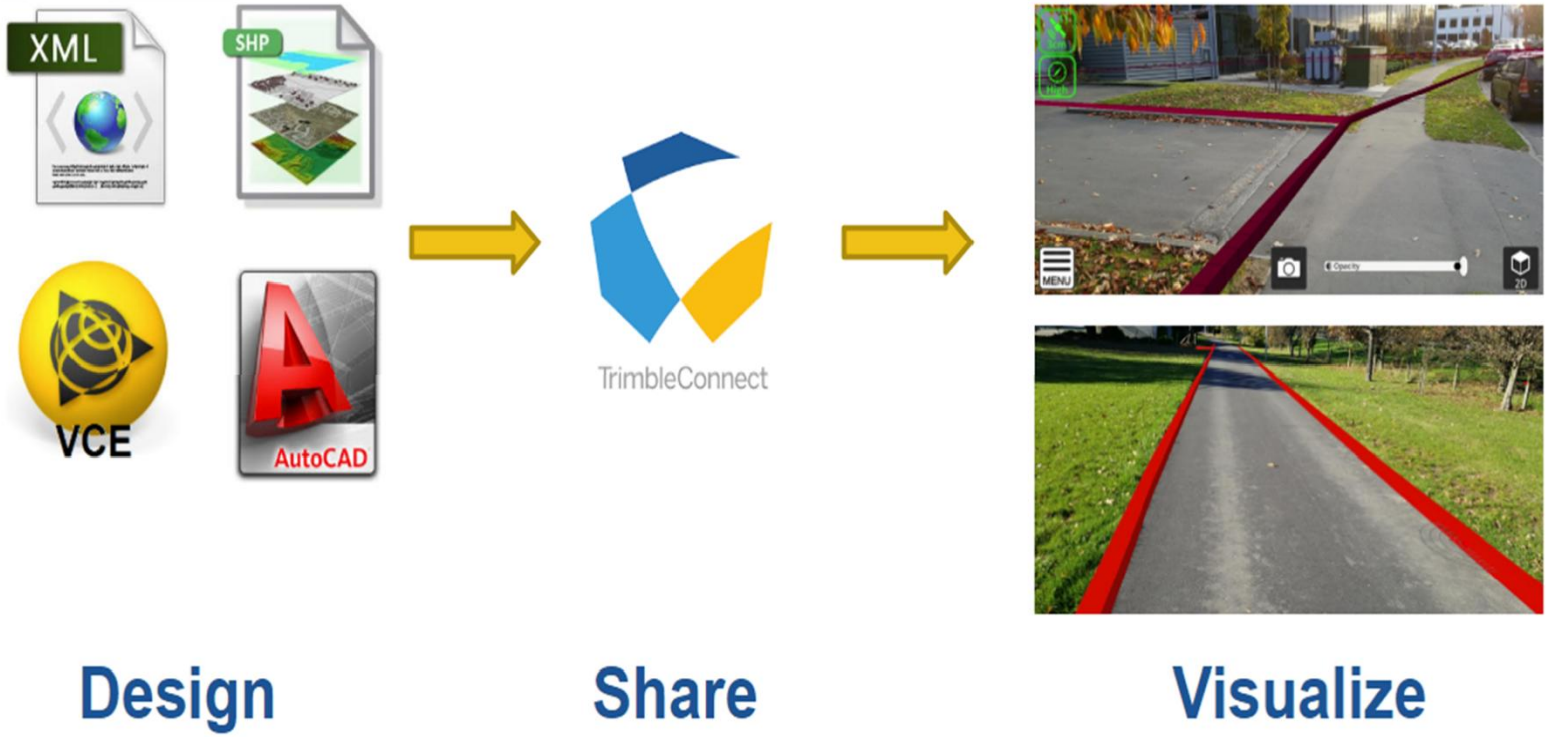
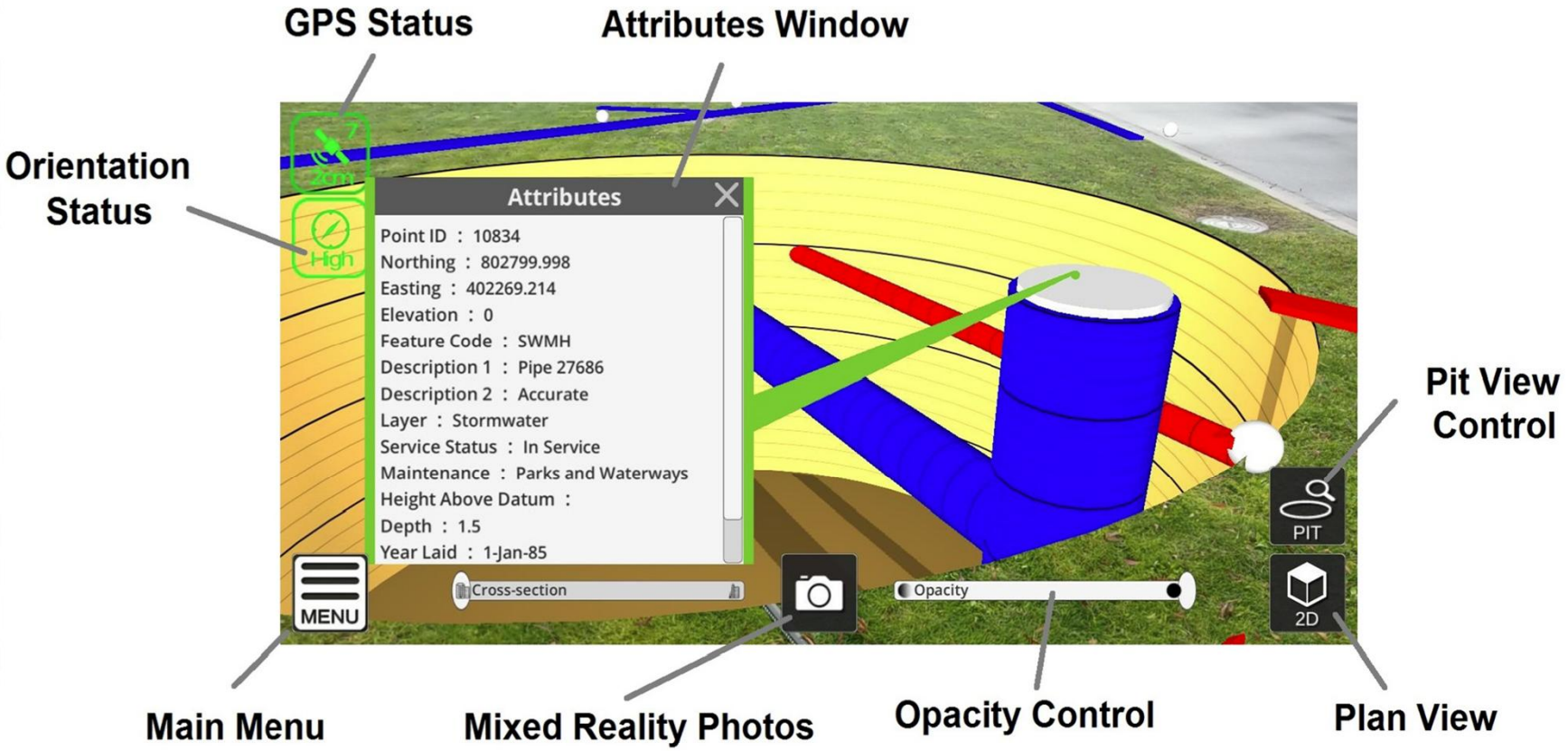
Boundaries

Line Work Formats: SHP, XML, DXF, DWG, VCE

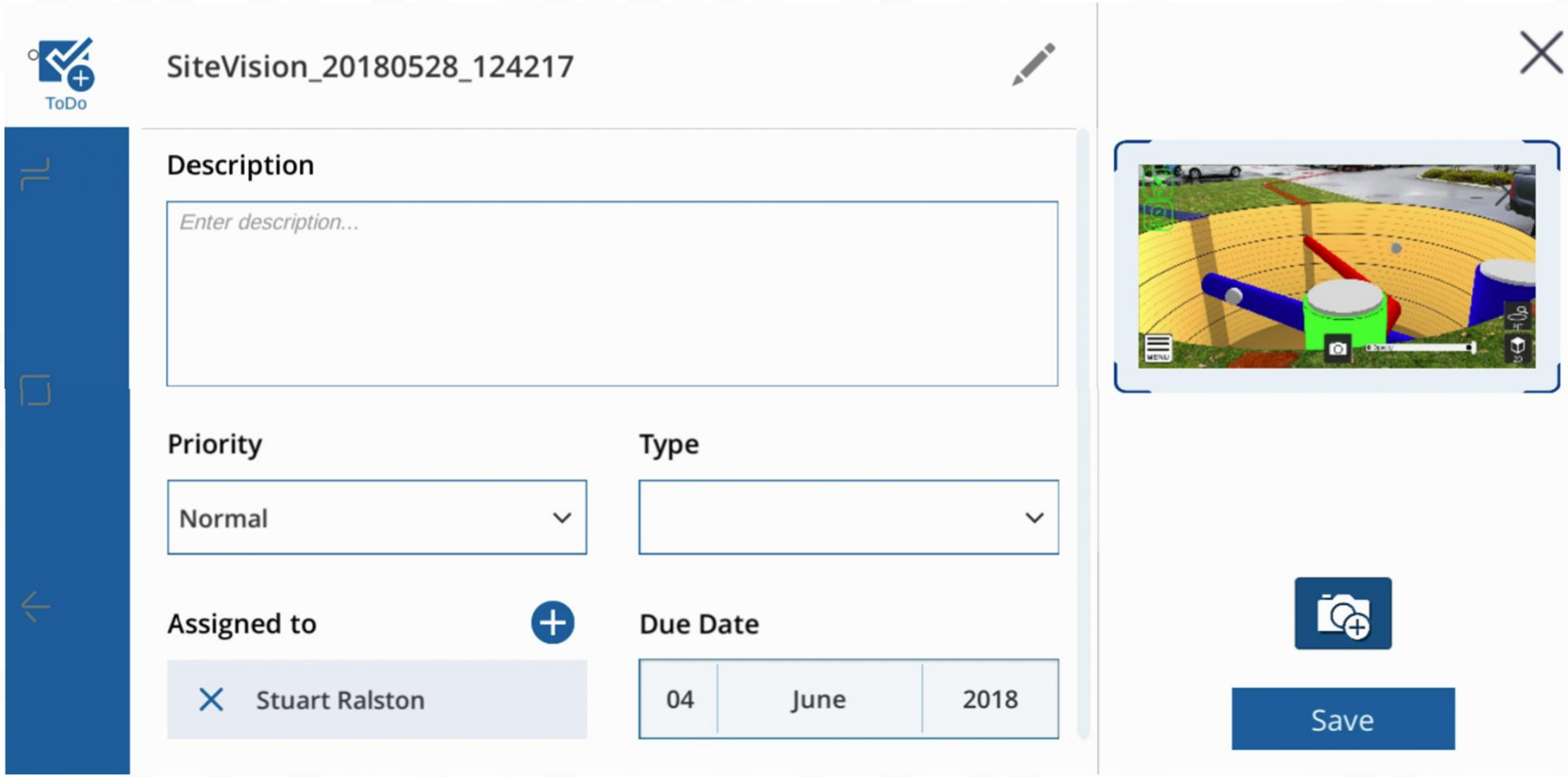


Other uses for Mixed Reality in the Field



Other uses for Mixed Reality in the Field

Reporting

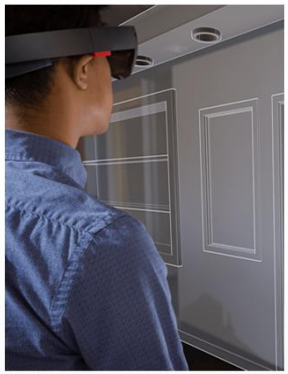


Mixed Reality for Vertical Construction

The vertical(building) construction market has several similar workflows to the civil/site segment, but they require different technology. MR/AR has the potential to be used even more in vertical construction.

Mixed Reality in Construction Today

SiteVision
SketchUp Viewer



Architects

Design Review
Stakeholder Buy-In

SiteVision
Trimble Connect

GC's

Model Coordination
Preconstruction
Training
Model Sequencing
3D Task
Management
Install Verification

SiteVision
Trimble Connect

Pre-Fabricators

Design Review
Guided Assembly
Remote Assistance

SiteVision
Trimble Connect

Subcontractors

Preconstruction
Model Sequencing
Guided Install
Remote Assistance
3D Task
Management
Install Verification

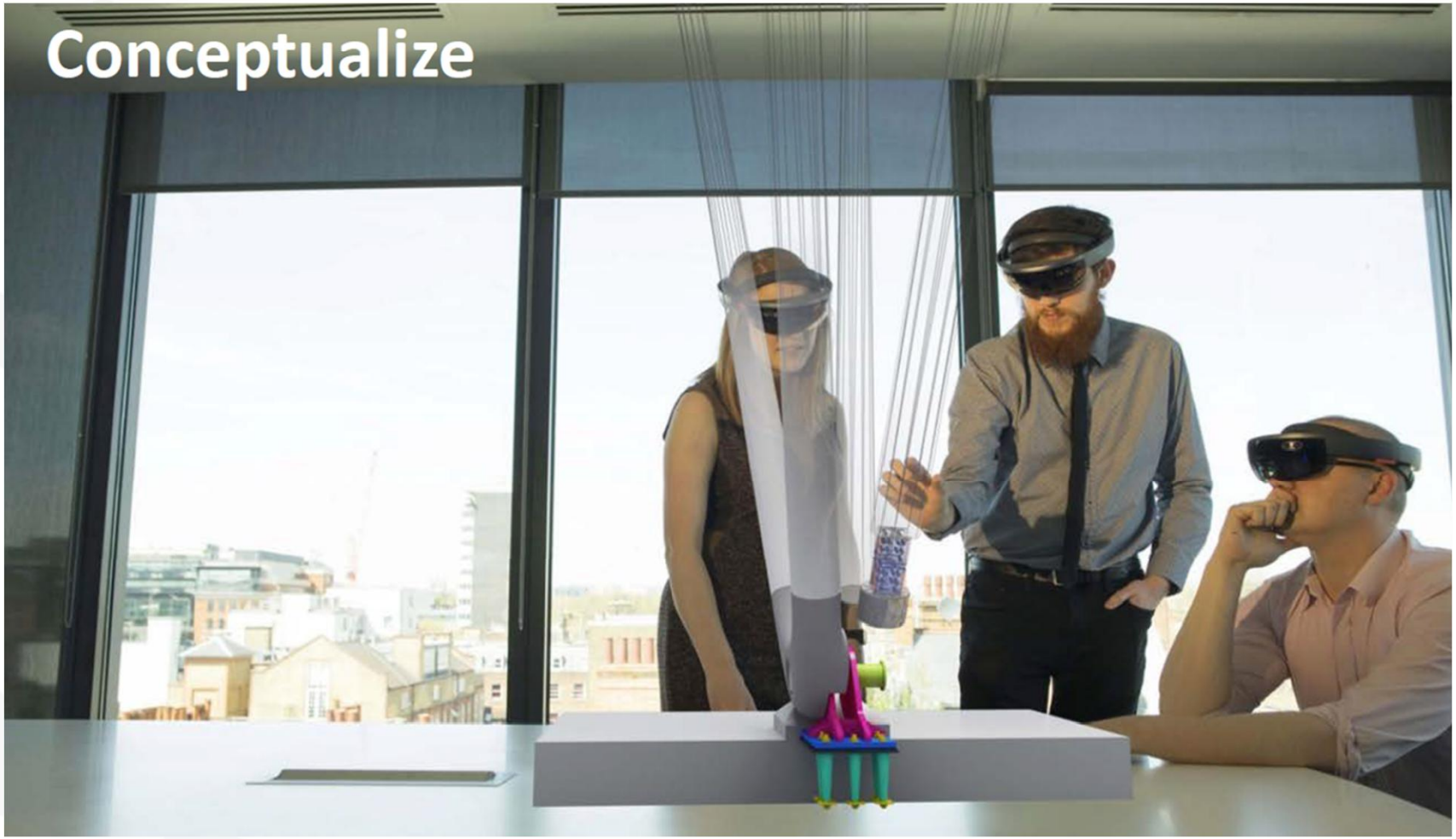
Maintenance

Hidden As-Built View
3D View of IoT Data
3D Task
Management
Remote Assistance

BuildingPoint™

Trimble

Use Cases for Mixed Reality


Conceptualize

FRONTIER PRECISION — How You Measure Matters

FRONTIER PRECISION — How You Measure Matters

Mixed Reality for Verification

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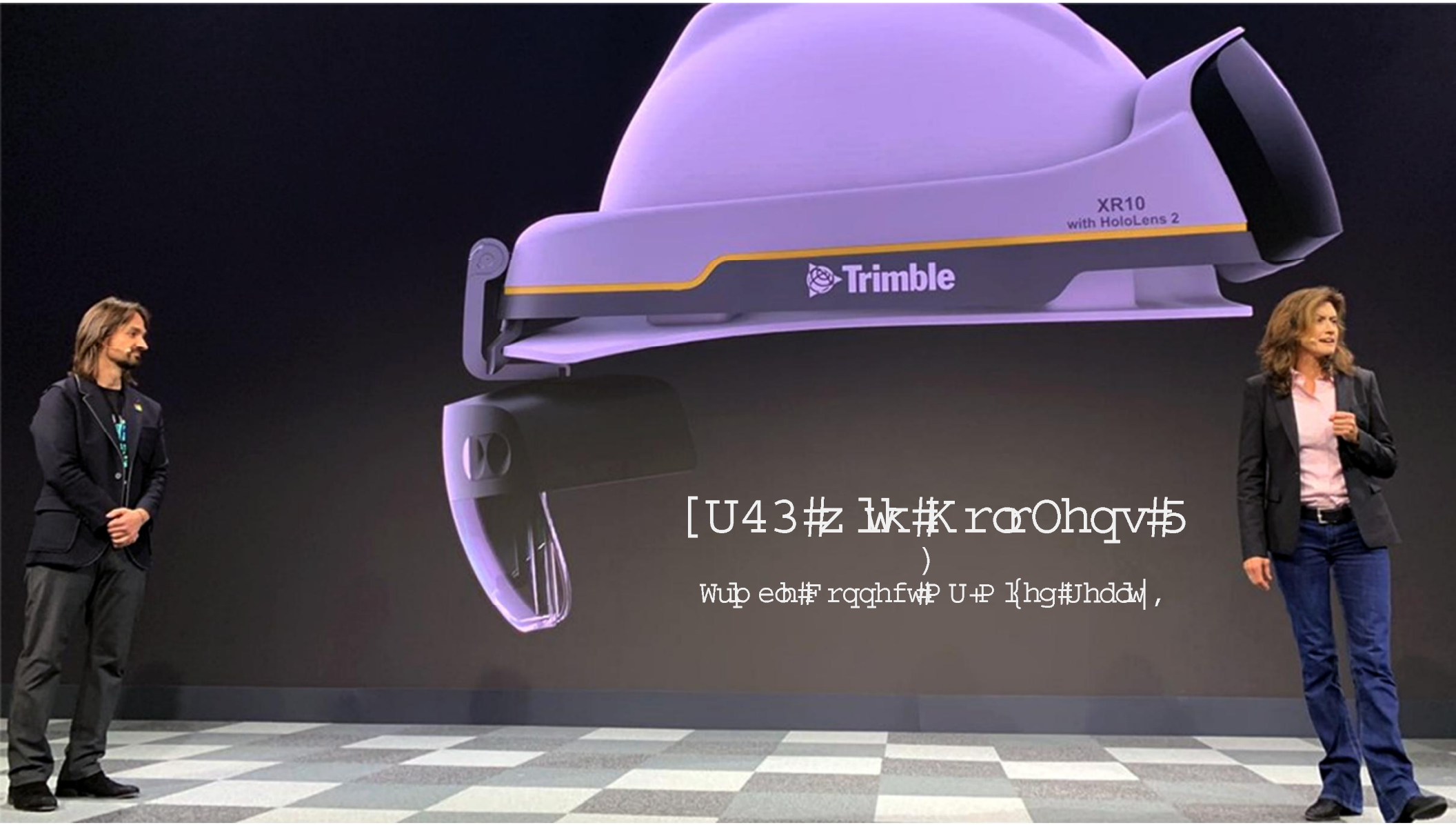

XR10
with HoloLens 2
Trimble

Multiple Solutions

XR10 with HoloLens 2

- Hard Hat only
- Uses heads up display
- Microsoft Hardware – Windows Operating System
- Uses planes for referencing model – not georeferencable
- Uses Wi-Fi
- Not great outdoors

SiteVision

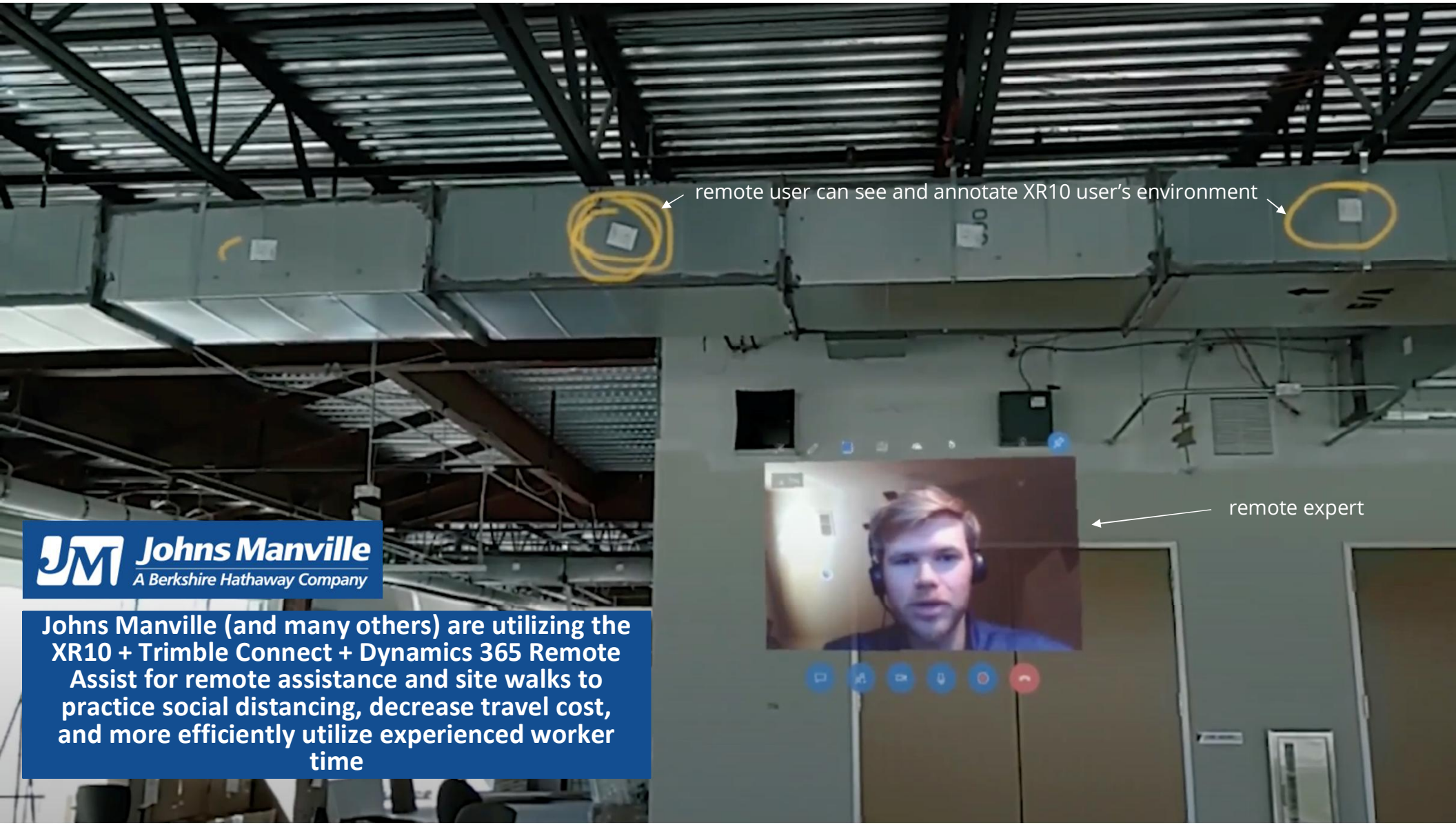
- Handheld
- BYOD
- Android only - today
- Uses GNSS for georefencing
- Needs correction service – Local / VRS / RTX
- Cell data plan required
- Not great indoors

Customer Examples

GA Smart Buildings is utilizing the Trimble XR10 with HoloLens 2 hardware and Trimble Connect for HoloLens software to improve prefabrication efficiency and ensure the quality installation of concrete columns in high rises.

- Example: Helios Project | Toulouse, France
  - Improved rebar assembly time by 18% through contextual training and visual guidance
    - $21,500 savings
  - 75% of typically expected rework avoided by ensuring installs happened in as-designed location
    - $23,000 savings

GA Smart Buildings plan to scale mixed reality technology to more onsite install QA/QC and expect to reduce project costs by 4-6%. On the Helios project alone, this would have contributed savings of $330k-$450k.



Johns Manville
A Berkshire Hathaway Company

Johns Manville (and many others) are utilizing the XR10 + Trimble Connect + Dynamics 365 Remote Assist for remote assistance and site walks to practice social distancing, decrease travel cost, and more efficiently utilize experienced worker time


CONSOLIS
2018
Pilot with Consolis
1st time assemblers wearing HoloLens build rebar cage 30% faster than trained workers
Efficiency in the production phase

Thank you for your time

Questions????