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Civil Engineering and Construction HW

CEC Autonomy

FTBA

February 2020

AGENDA

The industry is changing.
CEC is transforming it.

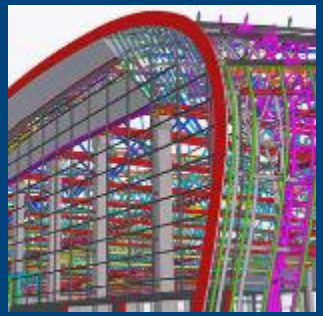
- Trimble Overview
- Transforming Construction
- Autonomy for Construction
- Earthwork Priorities

TRIMBLE

12,000 Employees in 35 countries and growing
Transforming the way the world works

Serving 5 of the worlds largest industries
Transforming the way they work

Agriculture



Building Construction

Civil Engineering and Construction

Geospatial

Transportation and Logistics

Our integrated technologies and innovation solutions are helping customers increase productivity and profitability across multiple industries around the world.

Transforming the way the world works

Transforming the construction industry <u>again!</u>

Conventional Construction

Digital Construction

Eliminated Process

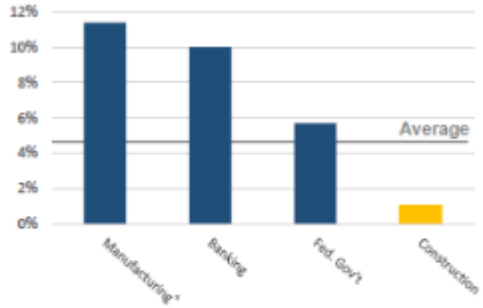
Data Driven Connected Construction

Optimize & Automate Process

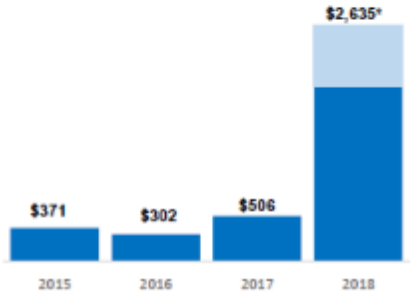
Positioning for Change

A Digital Transformation has begun. Data driven SW. Leading technology providers are building capabilities

Massive Underinvestment in Tech



Total Capital Raised ($M)

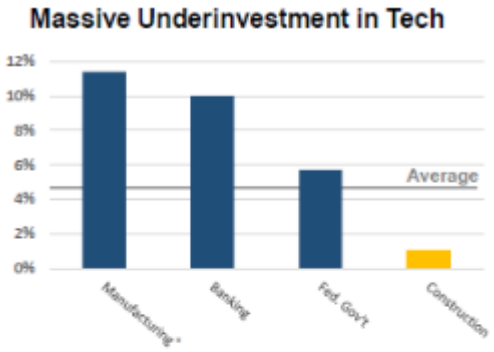


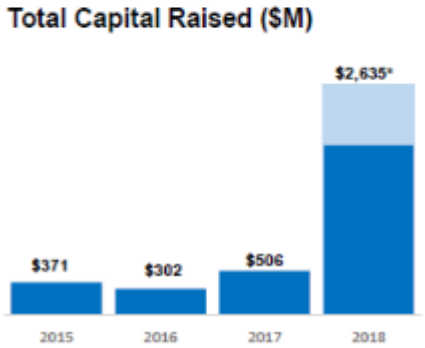
Most Active Acquirers of Construction Technology Since 2015

Company	Deal Count	Construction Acquisitions
JDM Technology Group	7	ConEst Software; CostCon New Zealand; Estimate Software; IndustrySmarts; Integrity Software; Plusfactor; Rendra
Trimble	7	E-Builder; Stabiplan; Viewpoint; Building Data; Linear project; Sefaira; Vianova Systems
Bentley	4	S-Cube Futuretech; Synchro Software; Acute3D; EADOC;
HEXAGON	4	AGTEK Development; Catavolt; Multivista Software; NESTIX
NEMETSCHEK	3	Design Data; dRofus; Solibri
ROPER	3	ConstructConnect; On Center Software; iSqFt
AUTODESK	2	Assemble Systems; Synthicity
constructconnect	2	PlanSwift Software; Quote Software
HYPHEN SOLUTIONS	2	BRIX Homebuilder Software; Pharaoh Information Services
ORACLE	2	Aconex; Textura

Positioning for Change

A Digital Transformation has begun. Data driven SW. Leading technology providers are building capabilities





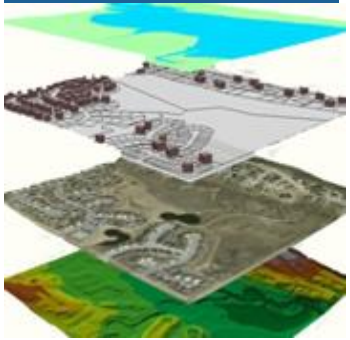
Date Announced	Target	Acquirer	Enterprise Value ($M)	Target Rev. ($M)	EV / LTM Rev.	Target Description
Apr-18	VIEWPOINT	Trimble	$1,200	ND	ND	Provides construction industry ERP, accounting, project management, BIM, collaboration, mobile office and content management software and SaaS
Dec-17	aconex	ORACLE	$1,200	$123	9.7x	Provides team collaboration and document and project management SaaS for the construction sector
Jul-18	THE GORDIAN GROUP	FORTIVE	$775	ND	ND	Provides construction pricing data and procurement software for the construction sector
Sep-16	IRON PLANET	RITCHIE BROS. Auctioneers	$759	$126	6.0x	Provides an online auction site for the construction industry, enabling users to buy and sell used heavy equipment
Jul-15	EAGLEVIEW TECHNOLOGIES	Vista Equity Partners	$715	ND	ND	Provides online aerial 3D roof and wall measurement report data and project cost estimation for the insurance and construction industries
Jun-16	Textura	ORACLE	$663	$92	7.2x	Provides collaboration SaaS for payment management and project pre-qualification for the commercial construction industry
Dec-16	constructconnect	ROPER	$632	ND	ND	Provides data management SaaS to the manufacturing and construction industry in the United States and Canada
Jan-15	iSqFt	ROPER	$631	ND	ND	Provides online bid solicitation and preconstruction management solutions for contractors
Feb-18	e-Builder	Trimble	$485	$53	9.2x	Provides fully-integrated, owner-centric, cloud-based construction program management software
Feb-15	Constructionline	CAPITA	$53	$14	3.6x	Provides an online database of pre-qualified contractors, construction suppliers and construction consultants in the UK

Project, Site, Machine: Trimble owns the Machine, will own the Site, dogfight for the Project

Construction Cloud

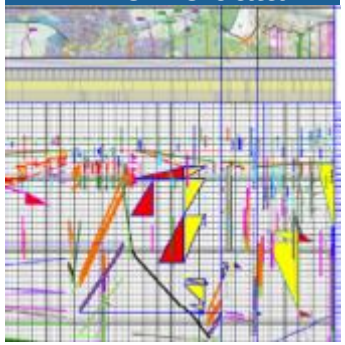
Data enables intelligence for automation
Construction Dashboard for real time project intel.

Geospatial data



BIM data

Project & Timeline data



Machine & equipment data

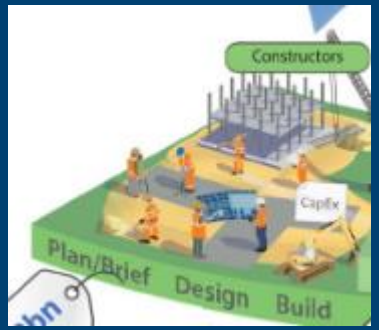
Financial & Supply data

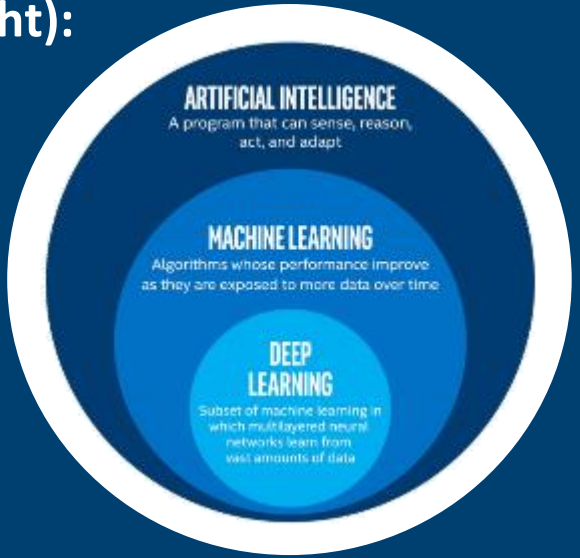
Visualize, optimize, connect, inform and automate construction process

Data powers AI, providing intelligent decision making for construction productivity and automation

From reporting (hindsight):

- Progress
- Expenses
- Alerts





To informing (insight):

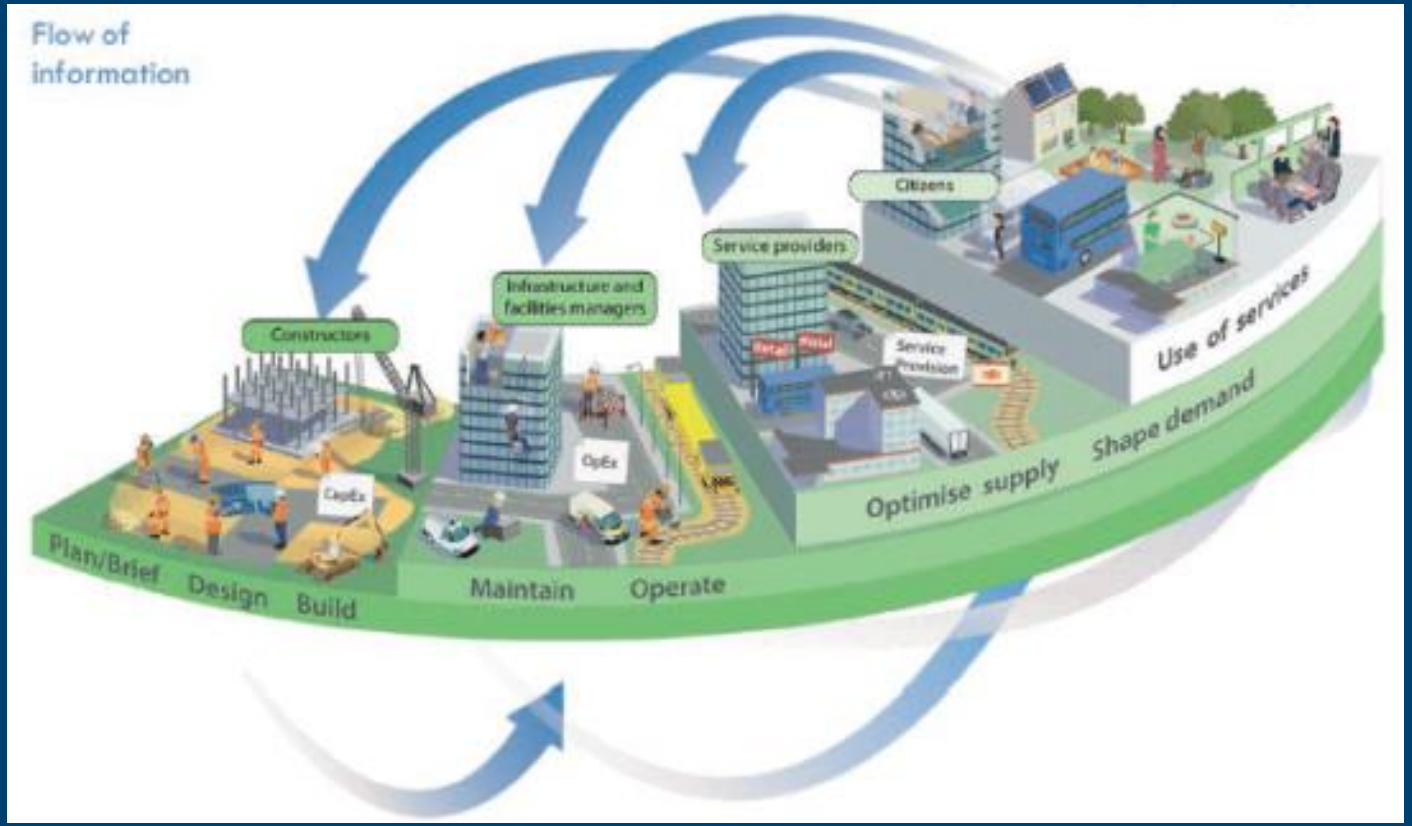
- How to finish faster
- How to finish cheaper

To automating:

- Estimates
- Schedules
- Work orders
- Machines

Industry Trend: Chief Data Officers and data scientists being hired by leading contractors

…..it will extend beyond construction to optimize and automate, design, maintenance and operation of our cities



Authoring Software - Trimble and 3rd party

CONSTRUCTION CLOUD: Data Collaboration and Analytics - Managing the field from the office

Business Intelligence – Live Site

Digital Asset and Data Management

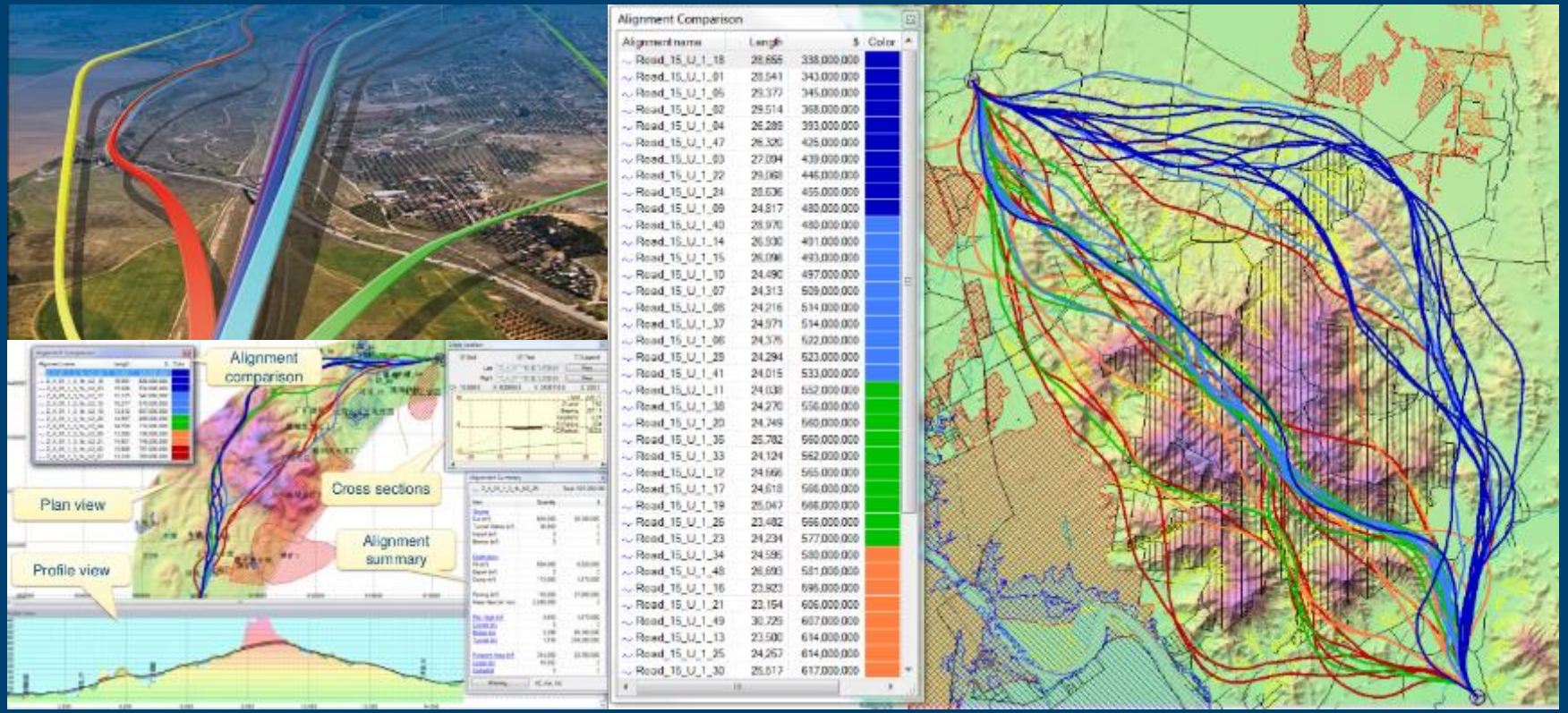
Constructible Data Model

VIANOVA Systems
A TRIMBLE COMPANY

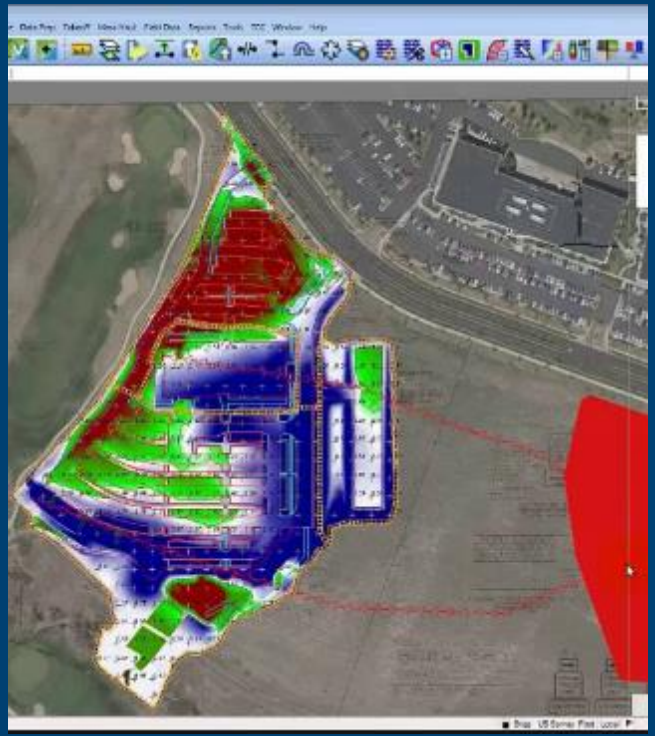
Connectivity Critical

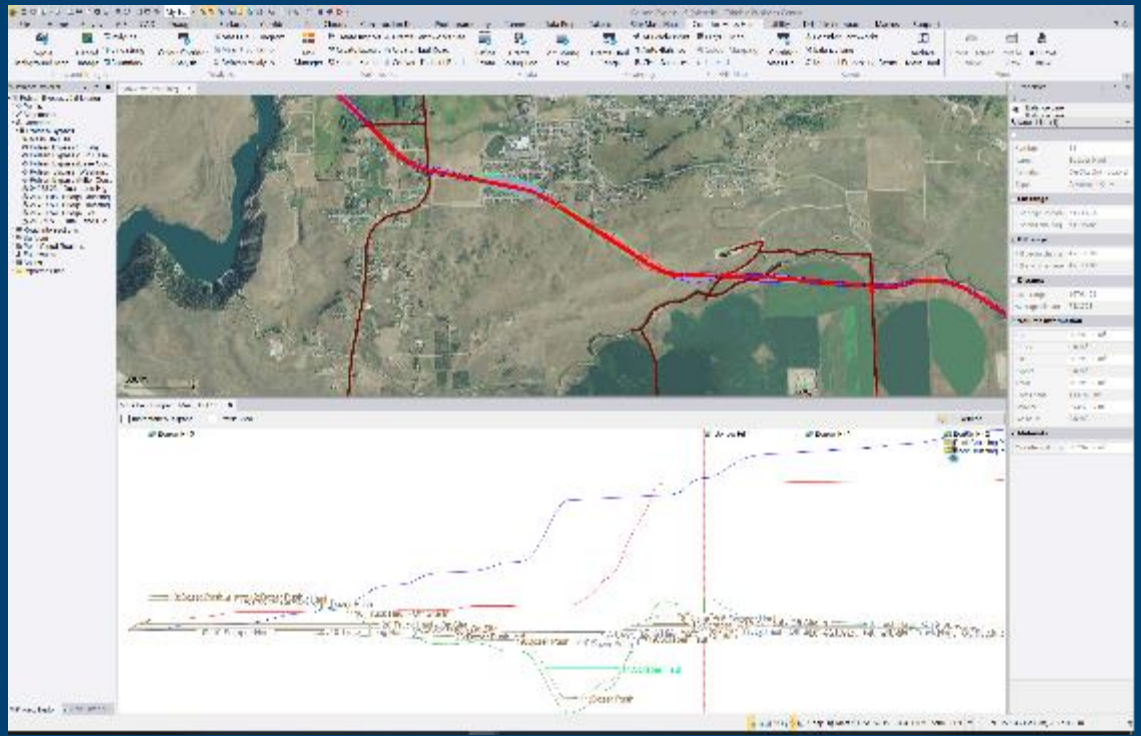
Across site and to cloud

Digital & Field Assets



Trimble has intelligent software that brings the same optimization to Construction



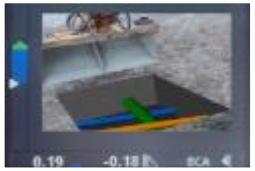


The same intelligence was added to TBC to optimize mass haul plans

and will add workflow intelligence on the machine

Product

HW & SW Plans highly aligned. **Parallel Development** progressing all elements for accelerated roll out

		Platform	Connectivity	Optimization/Safety	Automation
CEC HW Automating the Site	Field Solutions	New on & off machine platform's enabling the vision. UI rich capability 	**Data sharing between all site assets** High bandwidth connectivity **everywhere** Live collaboration/model 	**Real time** terrain updates Mixed Reality **Optimized** earthworks **Sequence** automation Personnel awareness & **Safety** lockouts 	**Redundant** positioning and connectivity **Continuous** site monitoring Real time optimization Task automation (repetitive & dangerous) 
CEC SW Connecting the Site	Office & Cloud Computing	**Digital Asset & Data Management** Site management portal and visualizer Open for all technology	**Data Analytics & Reporting** Insights "Digital Twin"	**Optimized processes** Machine Learning / AI Machine path planning and coordination	**Intelligent Site Command Center** Managing robotic equipment
CEC SW Connecting the Continuum	Office & Cloud Computing	**Construct Phase focus** Develop database user controls platform	**Design, Estimate, ERP** Live multi dimensional model	**Plan, Schedule, Manage** Develop database user controls platform	**Complete the Continuum** Survey. Plan

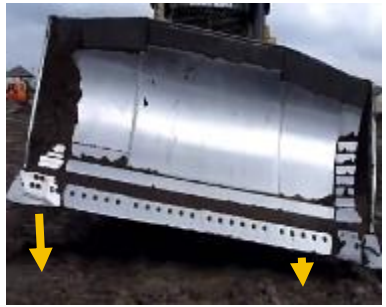
Advanced Automation Interest?

- What is your interest in autonomy?
- Are you interested in being part of the development which can be a painful process?
- If so, what expectations do you have?
- What machines/projects/applications are of interest?
- Incremental or remove the man immediately?

CEC's Pursuit of Autonomy

Extend blade control to automate sequence/tasks then industrial robots

Automation is not new to CEC but it is limited task control (Blade & Steering)



Factors driving increased levels of automation:

- Ballooning population driving infrastructure needs
- Increased productivity required
- Skilled labor shortages
- IT capable workforce
- Higher safety regulations
- Todays automated solutions do not offer the intelligence of experienced operators

Autonomy

Robotic machines need intelligence if operator is removed.
Elements of the Site Super and Foreman need automating too.

Need this…….

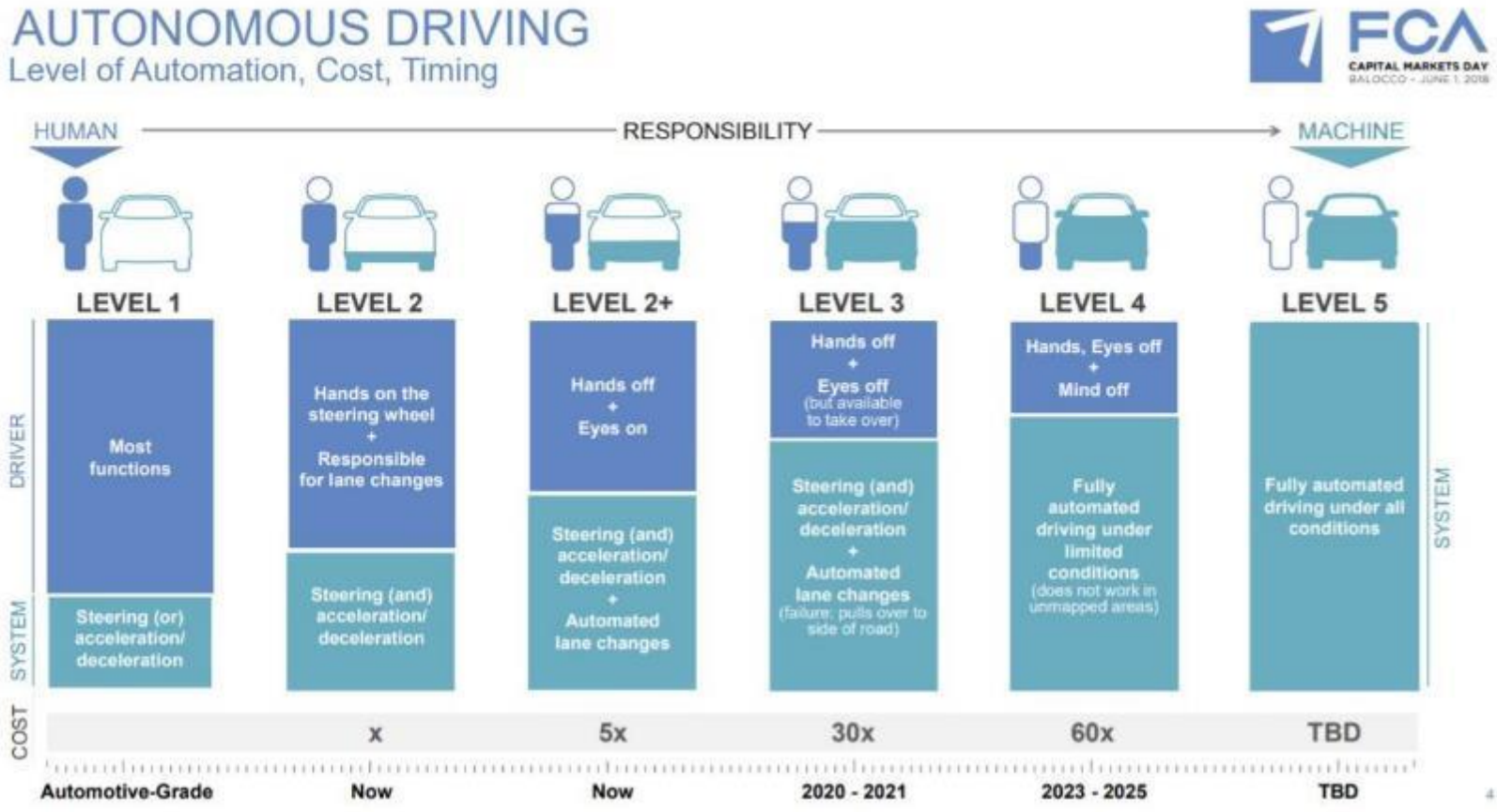
Within 5 years, it is predicted that AI will be used for:

- Scheduling & coordination of work — 79%
- Allocation of tasks across a mixed workforce of humans and machines — 69%
- Matching customer service agents with customers — 75%
- Quality control — 76%

> Although machine automation will get the most attention for the foreseeable future, it is actually the intelligence that goes into informing the machine how and when to operate that will bring the biggest benefits

……..to instruct this

Levels of Autonomy



Advancing Automation, Where to start??

Asphalt Formation	Pads / balanced sites	Batters / Ponds / Pads	Spreading
Roads & Pads	Spreading (fill)	Truck Loading	Off Highway
Large Projects	Slot Dozing	Trenching	Quarry

Initial Autonomy Opportunities




Machine type challenges

Complex areas, live roads, limited tech today, coordination with other machines.	Complex decision making for majority of applications. Simple applications small % of each machine use	Complex perception required, Many tasks performed by each machine. Many elements to coordinate	High speed increases safety concerns. Route changes often and are complex, on & off road.

So what happened on Trimble's hill in the desert east of Vegas in 2018? A fully automated construction site and infrastructure management system was deployed, operated, and adjourned in the real world, in real time, and for the whole world to see. *(American Surveyor)*

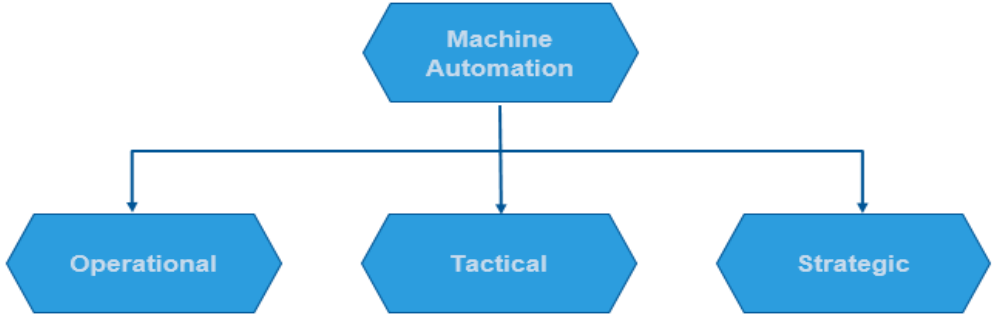
Trimble DIMENSIONS

Learning through demonstrations: 3 machines, 3 days, full autonomy

Accelerated through collaboration: Ag, Applanix, XYZ, CTCT, 3rd party

Autonomy

Robotising the machine one level at a time
Increasing levels of automation, safety & intelligence
Parallel dev. POC real world testing on customer sites



Level 2

- **Steering assist semi autonomous system with operator still present in cab** (Compactor, Dozer)
- Vision system included (mapping & SLAM) to collect site data for development of perception system in level 3. Firmware upgrade only.
- Leverage Earthworks sensors and displays
- Leverage AG steering, control code, and possible controller hardware
- Simple perception using radar
- Develop CEC box for tactical and operational controls

Level

- Steering and speed assist, semi autonomous system with operator still present in cab
- Object detection, alerting, collision prevention, as built maps
- Firmware upgrade to support advanced perception for **tactical** control and “as built” map collection
- Replay and compare operator workflows

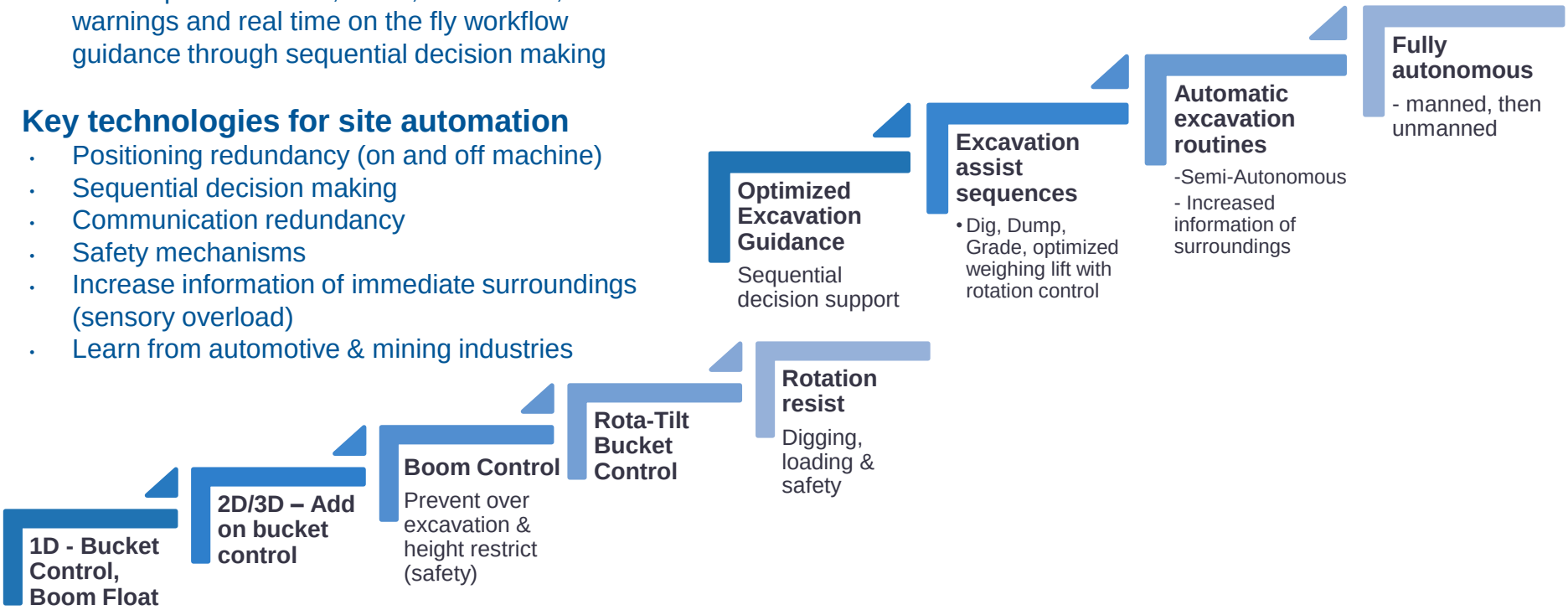
Road to Machine Automation (eg.Excavator)

Continually progress machine assist capabilities

- Add sequences assist, resist, awareness, warnings and real time on the fly workflow guidance through sequential decision making

Key technologies for site automation

- Positioning redundancy (on and off machine)
- Sequential decision making
- Communication redundancy
- Safety mechanisms
- Increase information of immediate surroundings (sensory overload)
- Learn from automotive & mining industries



Innovating together

Developing autonomy incrementally with a small number of partners

- Need right applications, projects, machines,
- Development understanding (timelines, identifying & solving problems and safety regulations)
- Inform of challenges & workflows to improve
- Measure and inform of benefits/value
- Incremental roadmap (achievable vs value)
- Create awareness – marketing for both parties

Interested partners: USACE, OEM's, Tech companies, Leading contractors WW

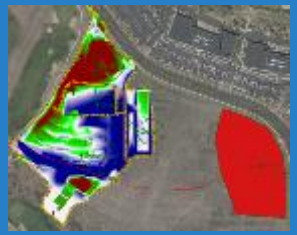
Fulfilling The Vision

Automation

Optimization

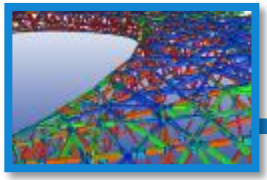
Connectivity

Platform



We differentiate at the connection of the digital and physical worlds

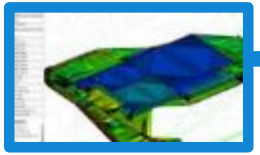
Construction



3D model at anchor bolt level detail drives pinpoint construction accuracy during fabrication and construction

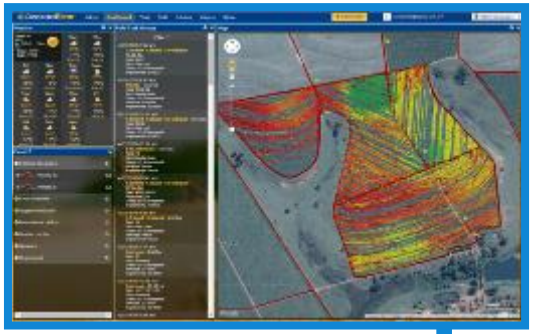
3D design model imported to the machine control and guidance equipment in the field

Construction verification against the model



Progress monitoring enables schedule optimization

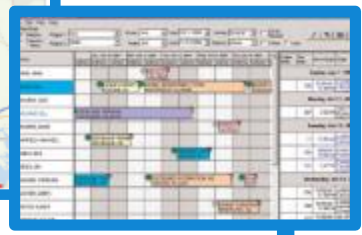
Agriculture



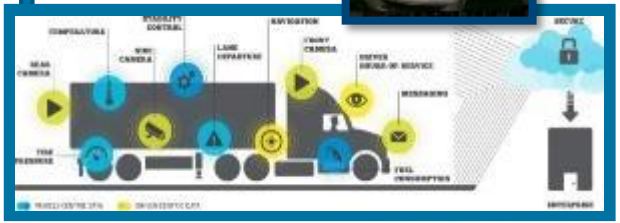
Real-time field conditions update and inform optimal farm management plan

Farm/crop management plans flawlessly executed in the field

Transportation

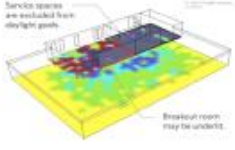


Real time road, vehicle, and driver conditions aligned, managed and optimized to meet customer needs

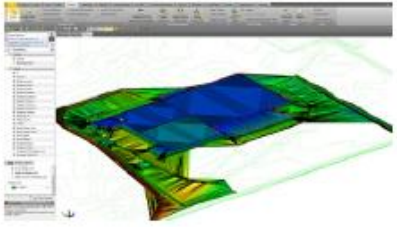


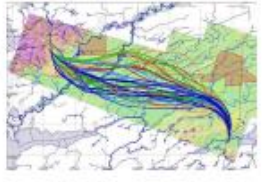
Connected, Content-Enabled, Constructible

Architectural

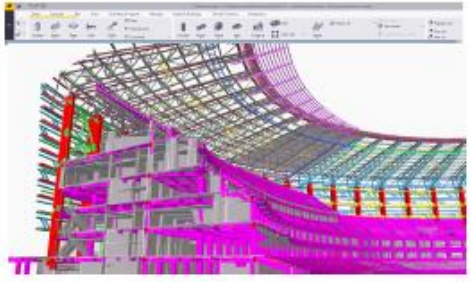


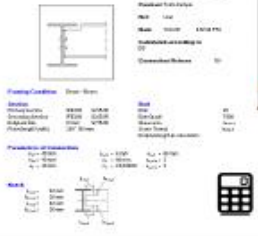
Civil



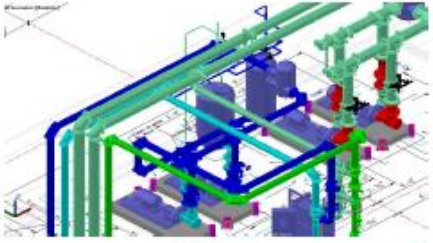


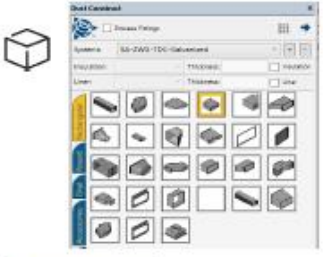
Structures





MEP





Thanks