AAPA
Facilities
Engineering
Seminar
November 9,2007

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Equipment for yard automation

Topics

1. **Introduction & experience**
2. **Automation features**
3. **Crane mechanical design**
4. **Interfaces**
5. **Conclusion**

Key facts about ABB

- Headquarters: Zurich, Switzerland
- About 108,000 employees in around 100 countries
- Orders in 2006: $28.4 billion
- Revenues in 2006: $24.4 billion
- Listed on Stockholm, Swiss & New York exchanges; traded on virt-x

ABB Crane Systems – A brief history

1883 Company ASEA was founded in Sweden
1897 Delivery of first crane equipment
1968 Delivery of first container crane with thyristor drives
1979 ASEA concentrates on electrical equipment
Divests mechanical part of manufacturing
1981 First sway control patents
1987 STS crane with AC drives, Electronic Load Control System
1997 Unmanned stacking cranes introduced (Singapore)
2002 CTA, Hamburg in commercial operation
2005 Order for EUROMAX
2007 Order for TPCT/Taiwan and Busan + PNC/Korea

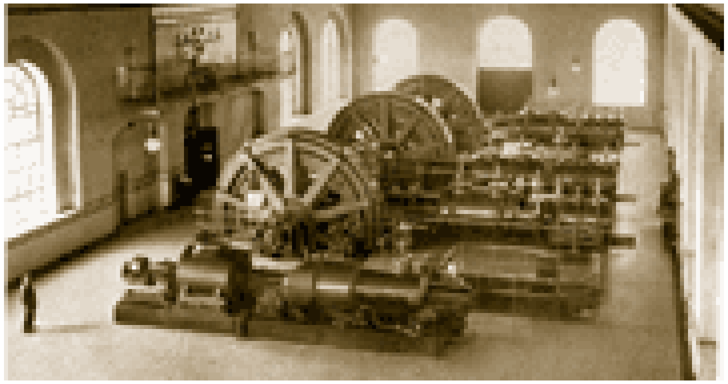

ABB scope

Electrical & automation equipment to crane builder:

- System integration
- Drives & motors (hoist, trolley, gantry)
- Trafos & HV/LV – switchgear
- E -house
- Process controllers & CMS
- Interface to TOS
- Sensors (LPS, TPS)
- Cameras
- etc

ABB Experience – auto RMGs in operation

Site	Project	Crane mfg	#	H	W	Vehicles	Yard/rail	Comment
Singapore	PSA	NKK	15	8	12	T/C/A	Good	Cantilever
Singapore	PSA	Mitsui	24	8	10	T/C/A	Good	Cantilever
Tokyo	Wan Hai	TCM	8	6	12	T/C	Slope	Cantilever
Kaohsiung	Evergreen	Chin-Pan	6	5	11	T/C	Fair	Cantilever
Hamburg	CTA	Künz	52	4/5	10	T/C/A	Bad!	Front -end
			105					

T = External trucks , C = Internal chassis, A = AGVs

ABB Experience – auto RMGs on order

Site	Project	Crane mfg	#	H	W	Vehicles	Yard/rail	Comment
Rotterdam	Euromax	ZPMC	58	5	10	T/C/A	Fair	Front-end
Taipei	TPCT	ZPMC	20	5	13	T/C	Fair	Cantilever
Busan	Hanjin	ZPMC	42	6	10	T/C	Fair	Cantilever
Busan	PNC	ZPMC	31	5	9	T/C	Fair	Cantilever
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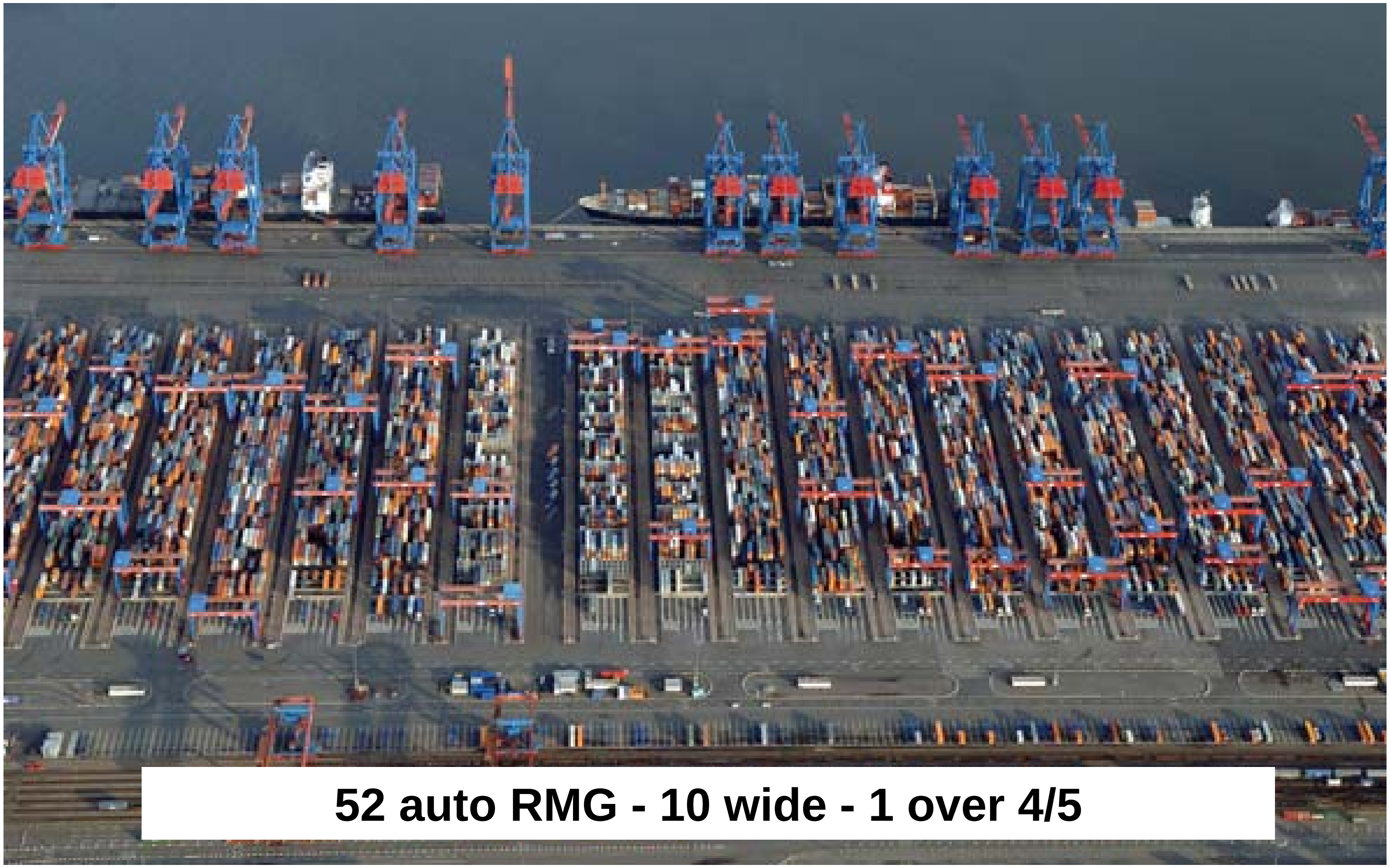
CTA – Hamburg - overview



52 auto RMG - 10 wide - 1 over 4/5

CTA - Operating experience

- Commercial operation since March 2002
- Capacity today about 3 TEU/year
- QC productivity 25-30 mph
- LS truck service 20-25 min
- Peak around 2000 trucks / day

CTA – auto RMGs

- **Total ARMG operating hours > 1 500 000**
- **Availability > 99%**
- **Container positioning and transport excellent**
- **“No” collisions involving automatic cranes**
- **> 15 000 000 moves**
- **15- 20 000 moves/day for auto RMGs**
- **Gantry travel distance > 8000 miles/y (13 000 km/y)**

EUROMAX, Rotterdam

Owner

Hutchison Port Holdings 100%
Hong Kong
(via ECT)

Capacity

Phase 1: 2 100 000 TEU/y
Phase 1-4: 5 000 000 TEU/y

Data

Quay 1500 m
Depth 17,5 m

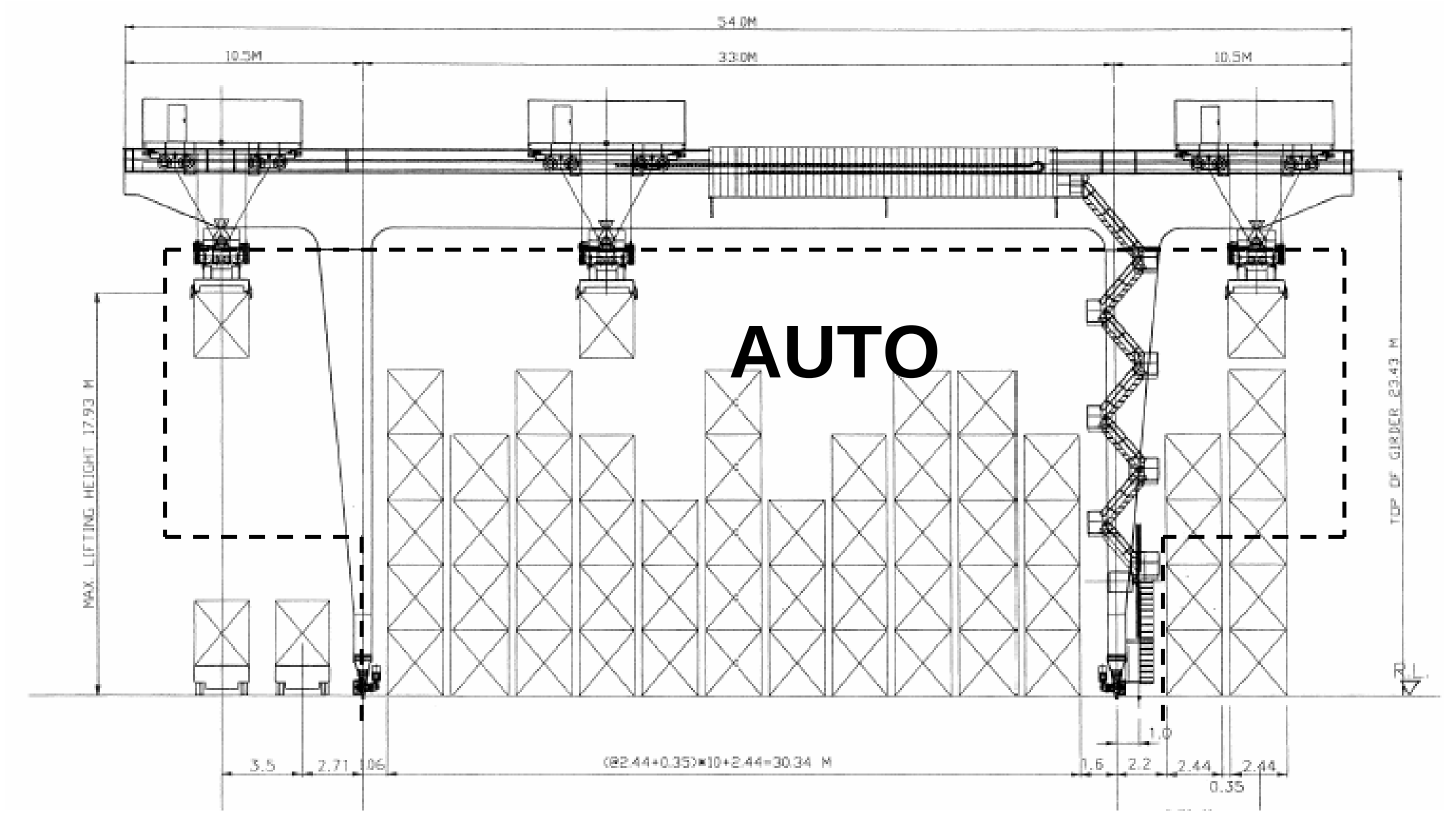
EUROMAX Rotterdam

- Scope phase I
  - **12 double trolley STS**
  - **4 barge/feeder QC**
  - **58 automatic RMGs**
  - **2 rail RMGs**
- Time-schedule:
  - **Delivery from fall 2006 – 2009**
  - **Start commercial operation 2008/07**
- Mechanical crane part by ZPMC, Shanghai
- **All automation and electrical equipment from ABB**

Site view 2007

EMC - Kaohsiung

EMC - Kaohsiung – Auto RMGs



All moves within marked area are fully automatic

Topics

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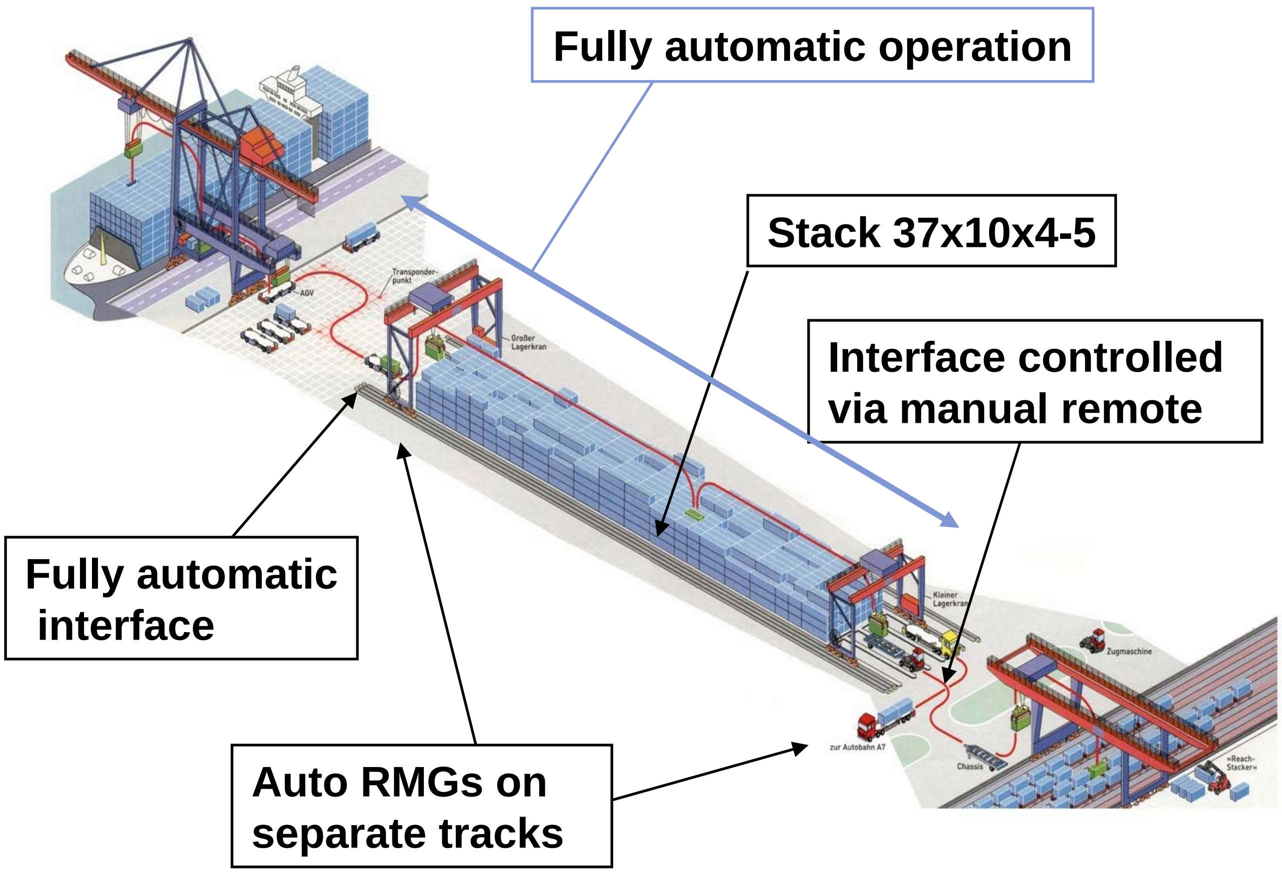
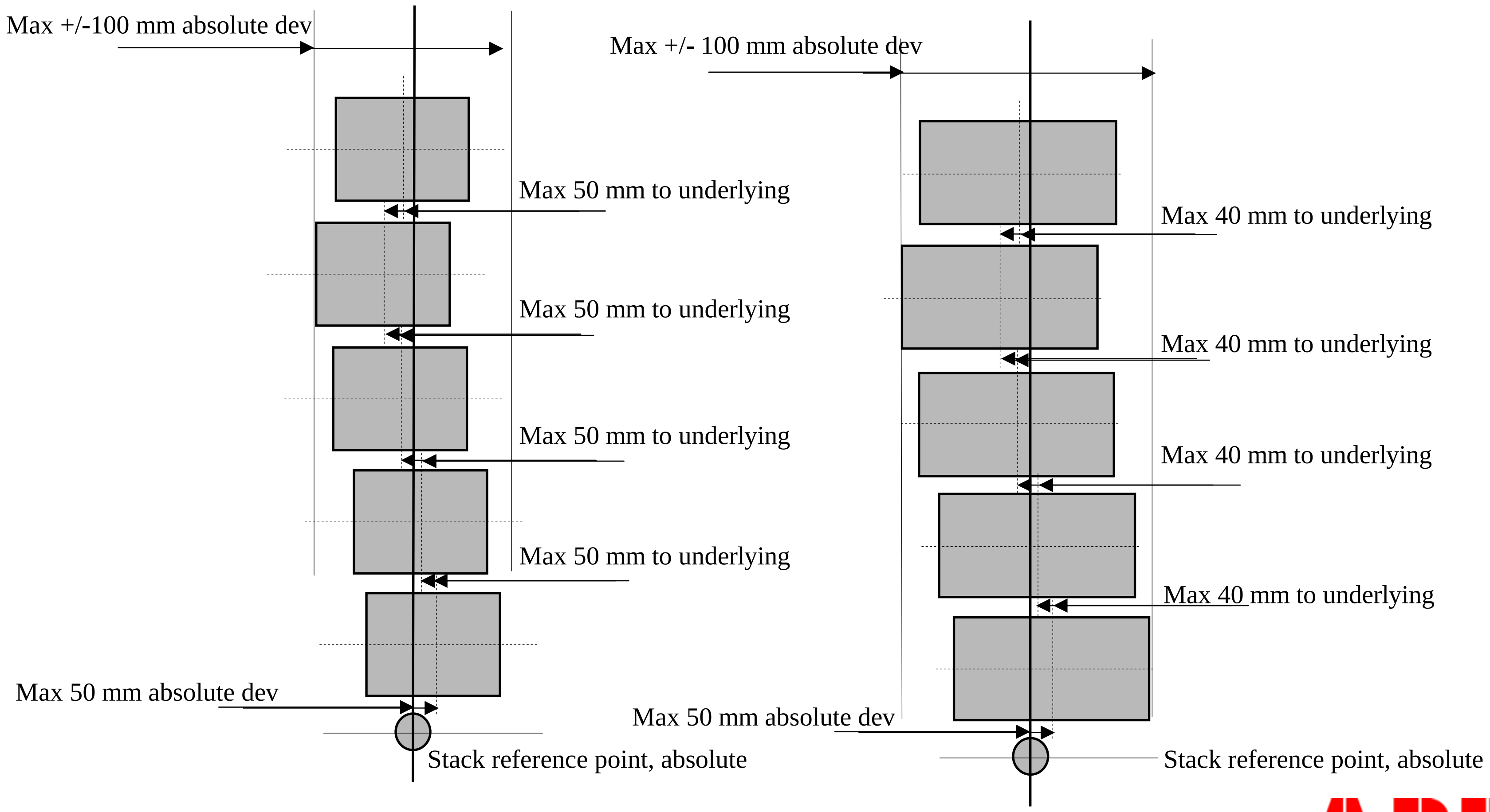
CTA – Container flow WS <-> LS



Automatic Stacking

Trolley direction, skew included

Gantry direction

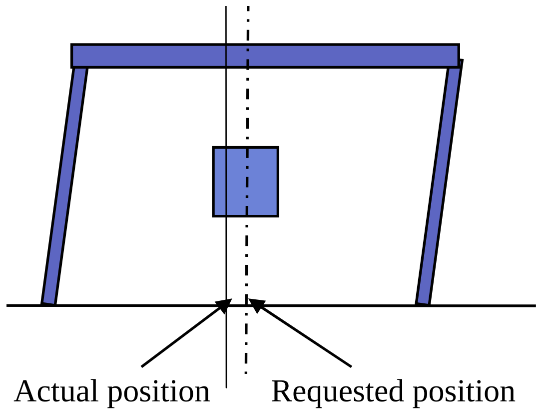


Automatic RMG challenge

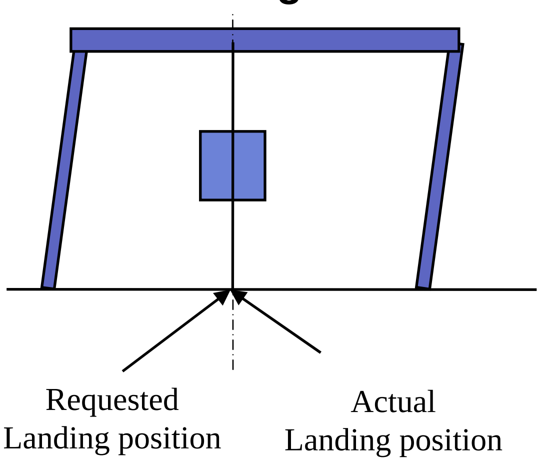
- **Problems to solve**
  - **Automatic job order handling**
  - **Anti-collision between cranes**
  - **Path control for avoiding obstacles**
  - **Efficient load control with centimeter accuracy**
  - **Finding the target position with centimeter accuracy**
  - **Handle ground/rail conditions**
  - **Handle crane dynamics**
  - **Automatic landing**

Crane Dynamics – Crane Deflection

Only Trolley & Gantry absolute position



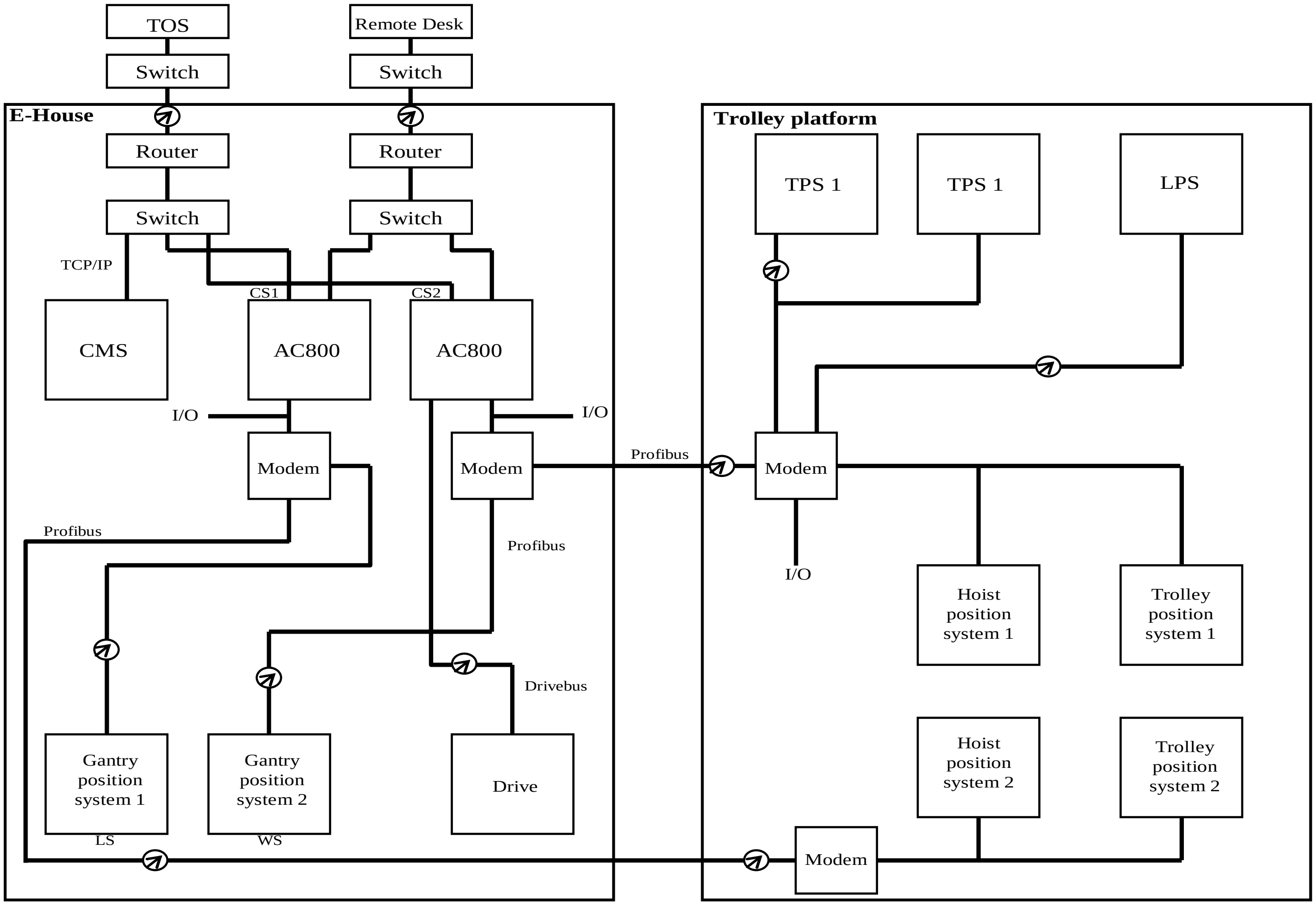
With TPS measurement relative the ground



If positioning is made based on gantry and trolley positions only,

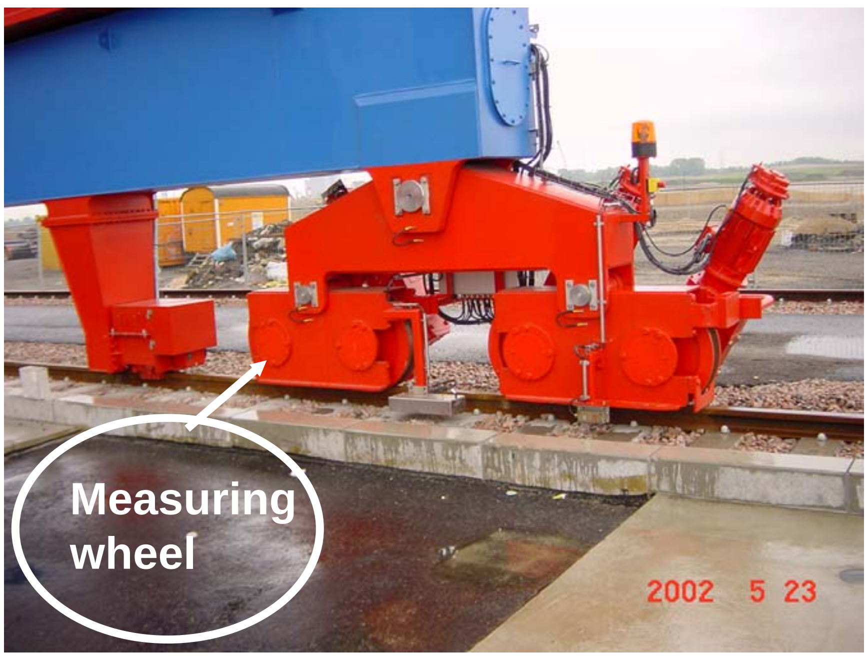
- The result will be influenced by:
  - Rail position and slope
  - Trolley rail slope
  - Girder deflection
  - Gantry wheel position on rail
  - Trolley wheel position on rail
  - Structure deflection
  - Load center of gravity influence on rope system
  - Load oscillation

Automation system lay-out

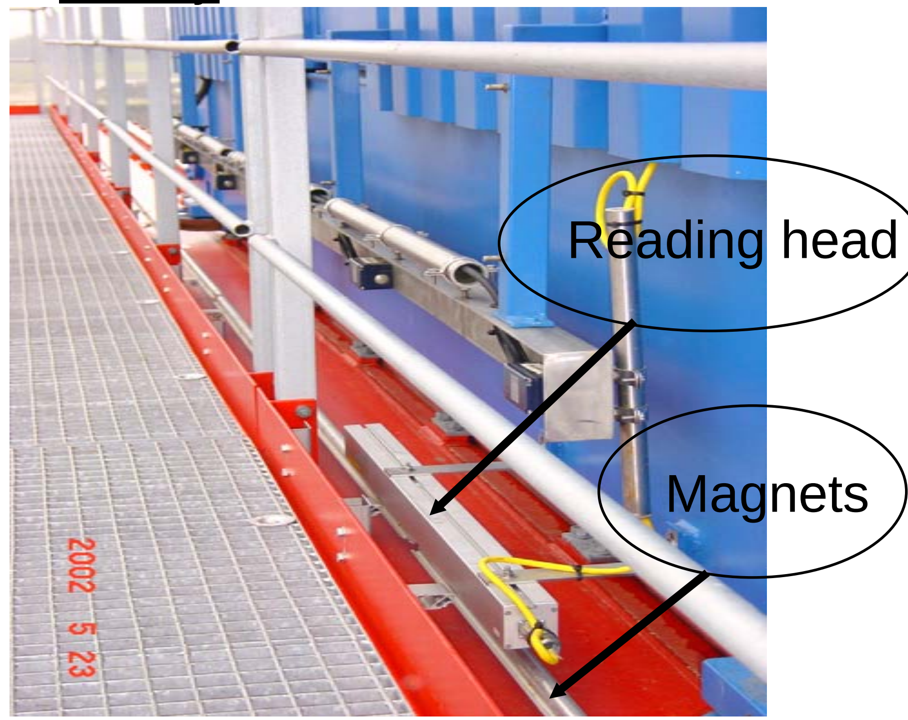


Positioning System – Absolute Position

- Positioning system is important for automatic cranes
- Most critical for the anti-collision systems
- Very important for placing first container unless ground markers are used.



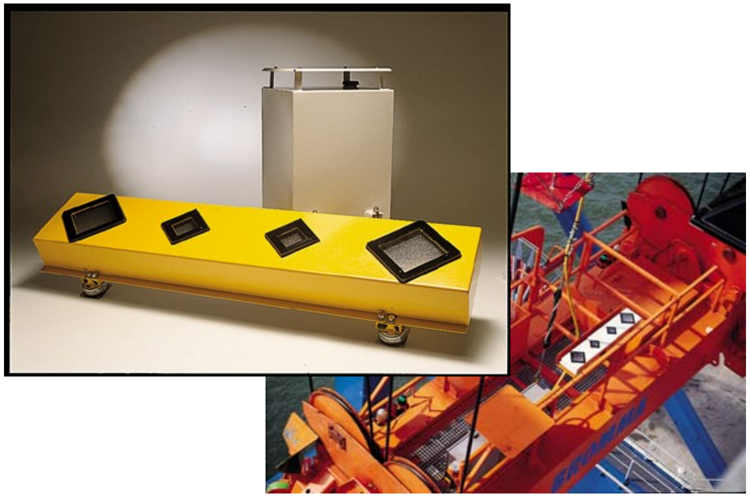
Trolley

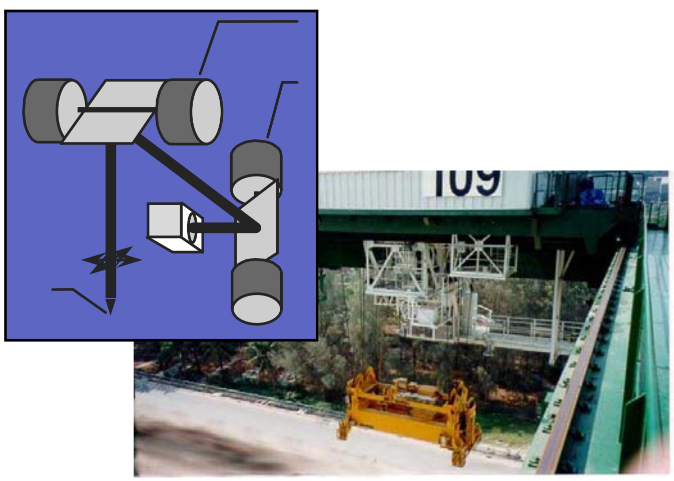


- Gantry
  - Optical system for calibration
  - Encoder for precise positioning

ABB

ABB - Crane Sensor System



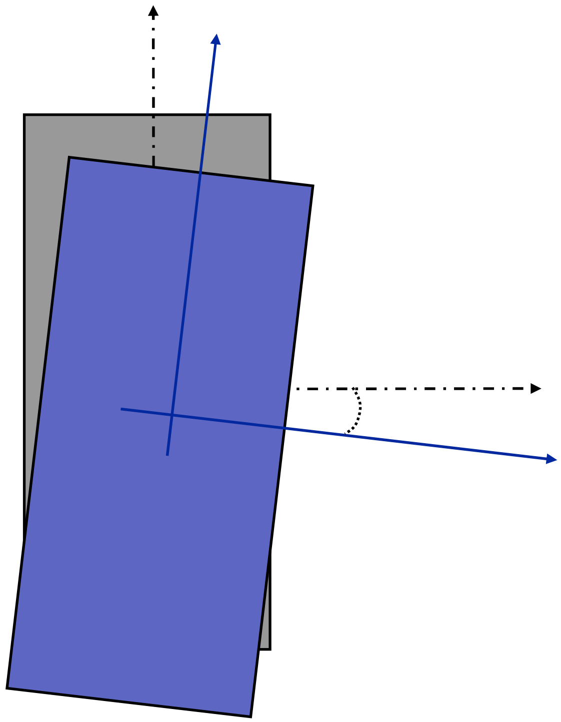


- Load Position Sensor
  - Developed by ABB crane organization
  - More than 200 systems in operation
  - In operation since 1988
- Target Position Sensor
  - Developed by ABB crane organization
  - More than 200 systems in operation
  - In operation since 1997

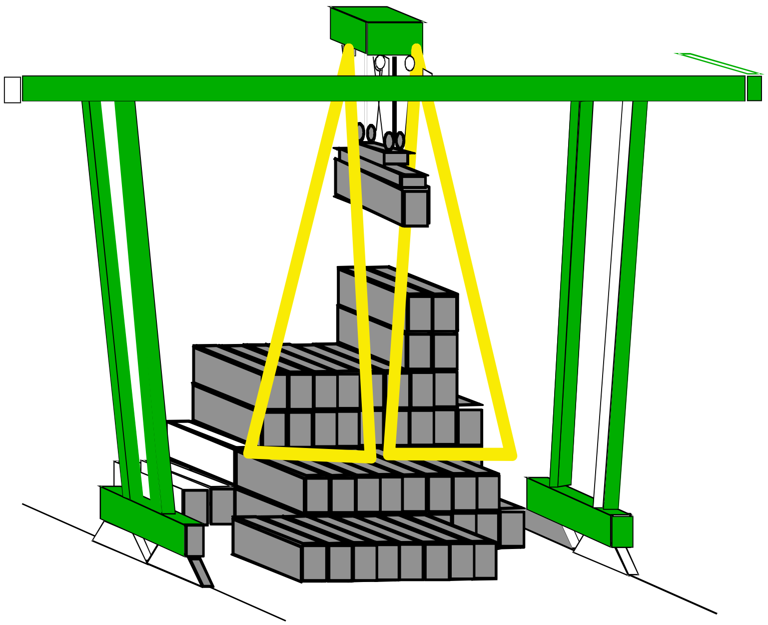
Load position control system (LPS)

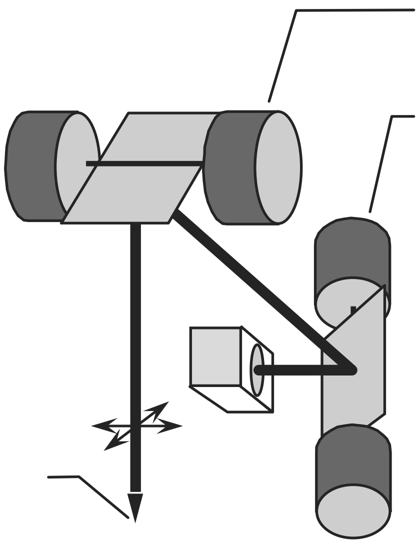
Control of the load position and motion relative trolley position

- Sway control
- Positioning / Path control
- Skew control
- 4 "directions":
  - Trolley position
  - Gantry position
  - Hoist position
  - Skew angle



Target Position Sensor (TPS)

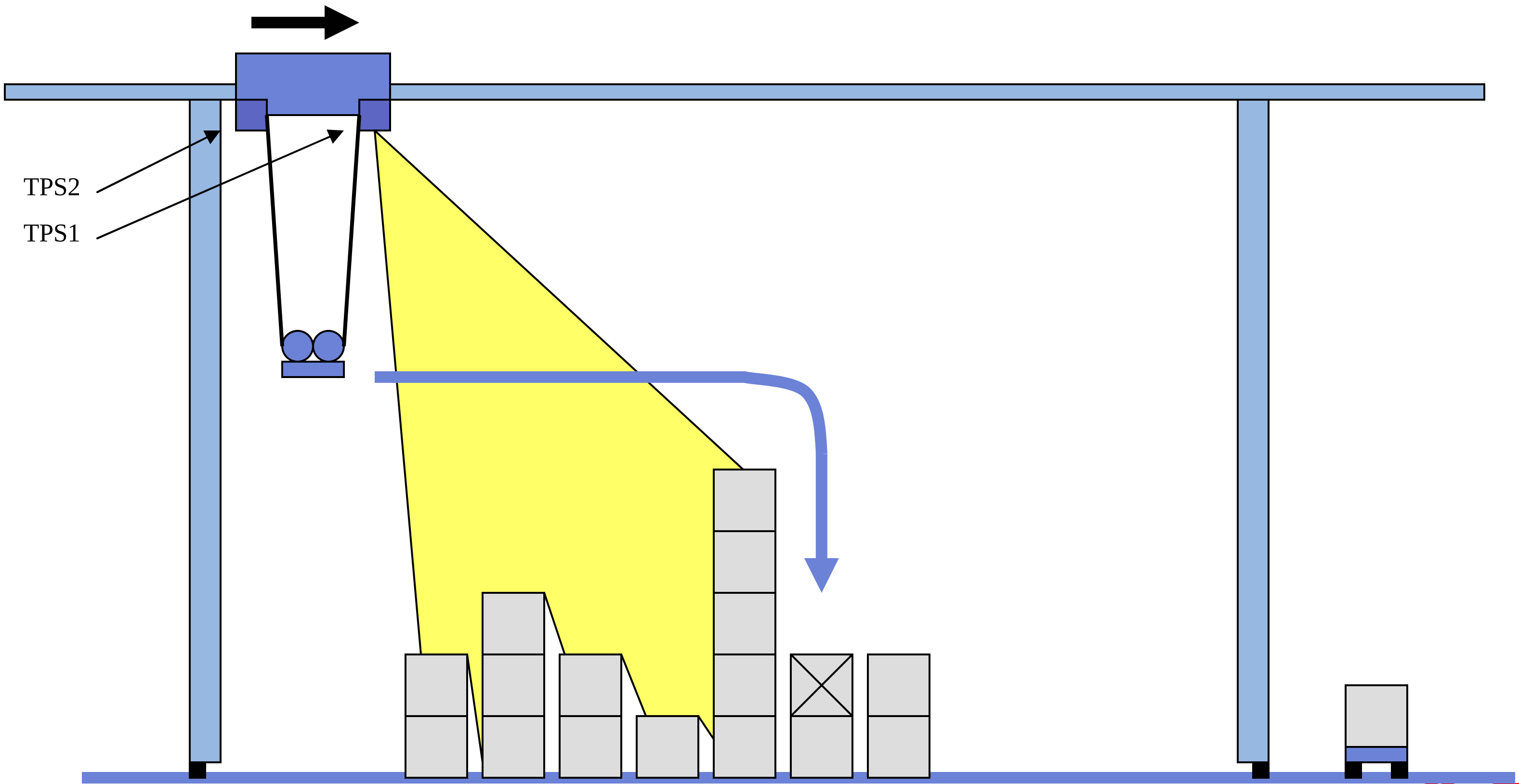




- Anti collision (stack, vehicles)
- Stack position measurement
- Stack profile scanning
- Vehicle position measurement (AGV/truck/chassis)

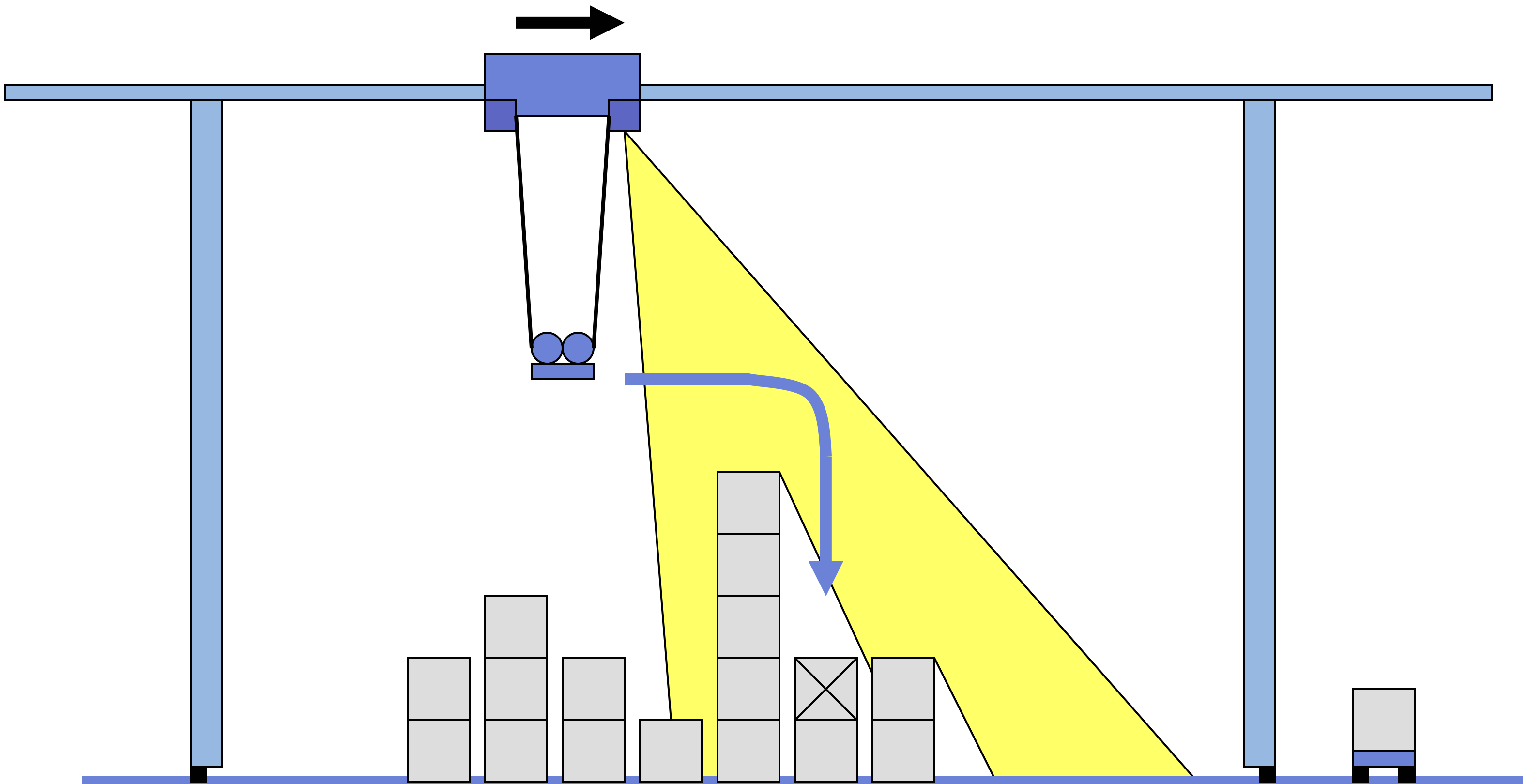
TPS job order

Pick up – anticollision scan



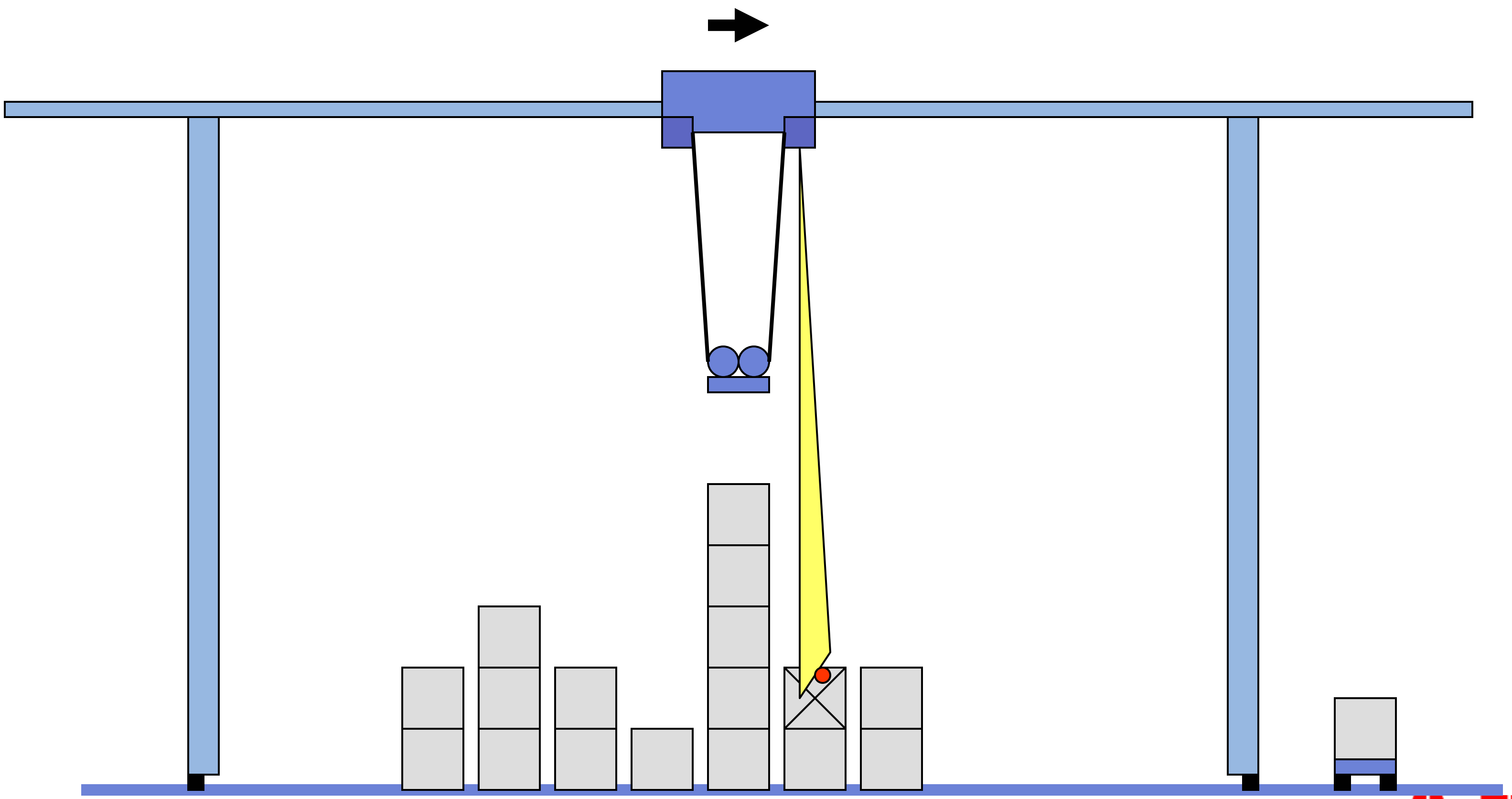
TPS job order

Pick up – anticollision scan



TPS job order

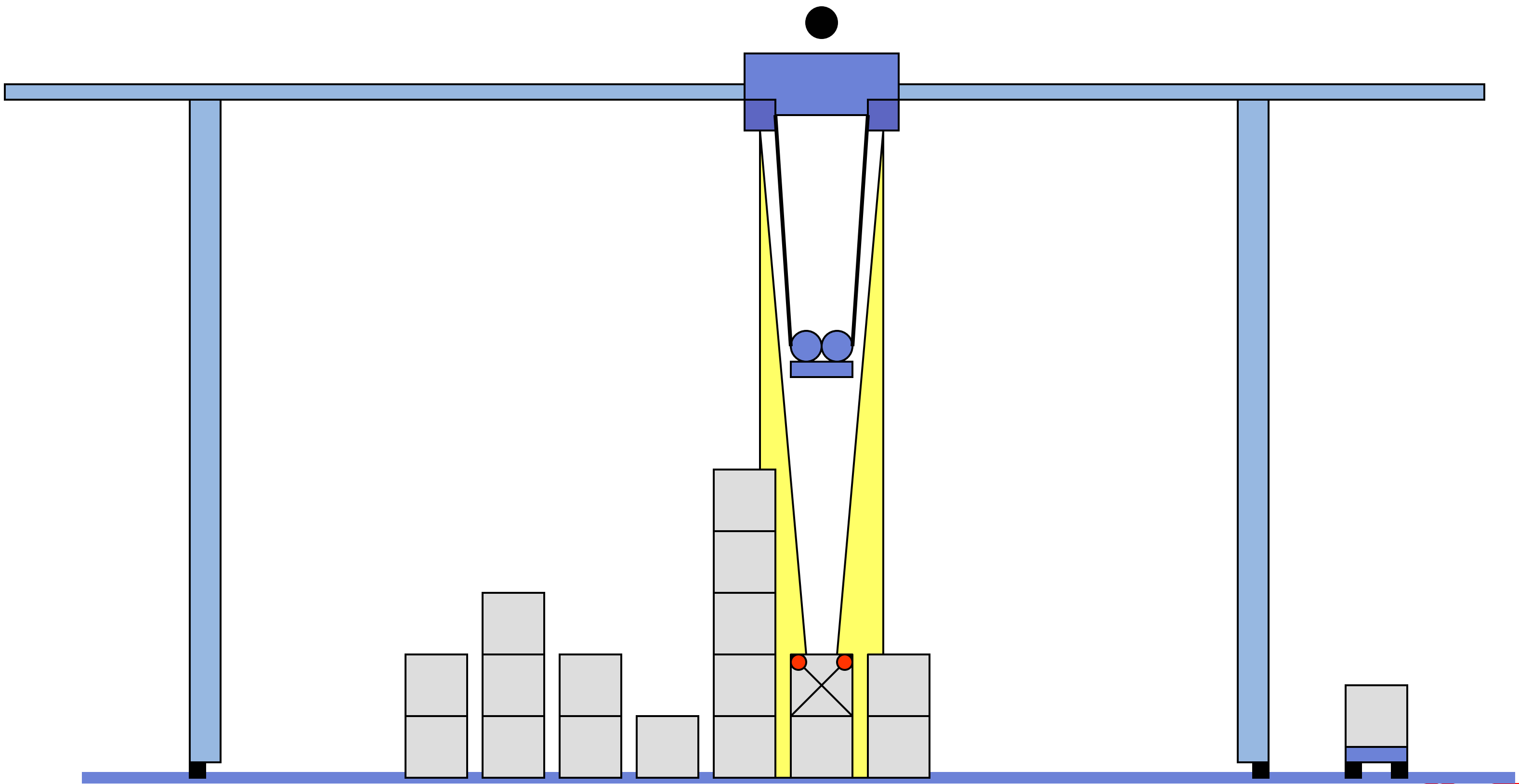
Pick up – fine alignment in gantry direction



TPS job order

Pick up – fine alignment in trolley direction

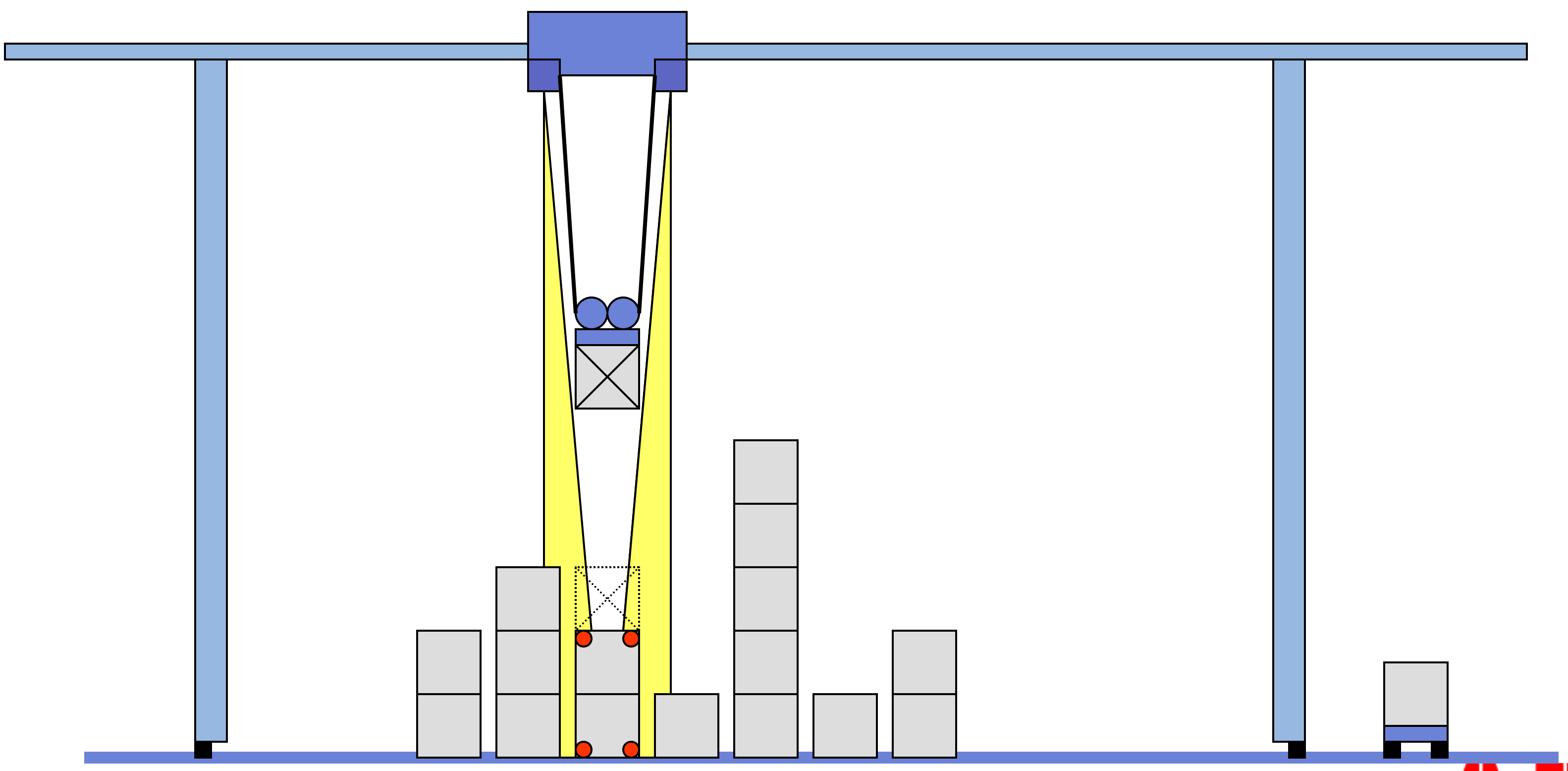
Find position of top container



TPS job order

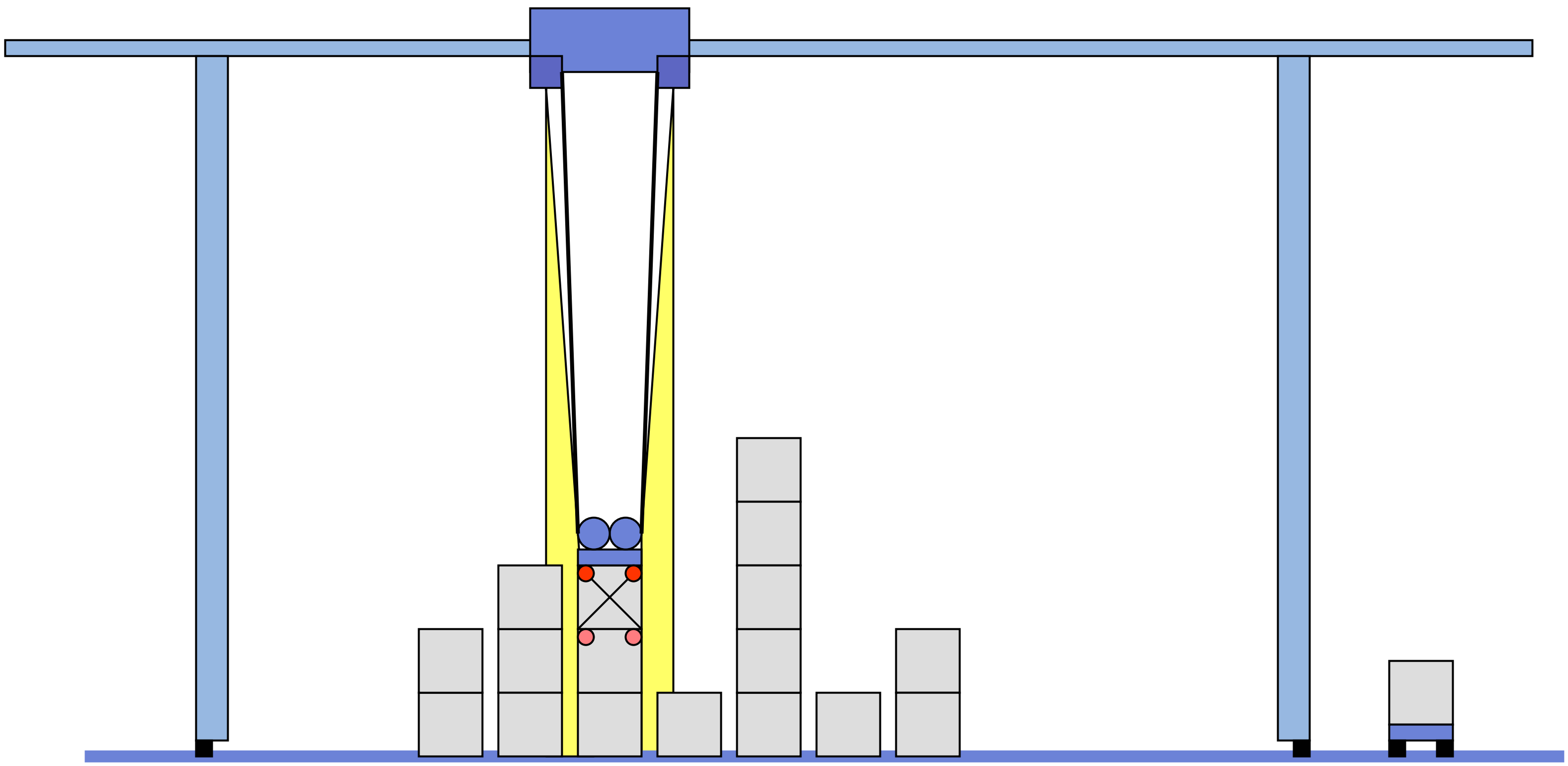
Set down – fine alignment in trolley direction

Find position of top and bottom container



TPS job order

Set down – measure difference between reference and landed container

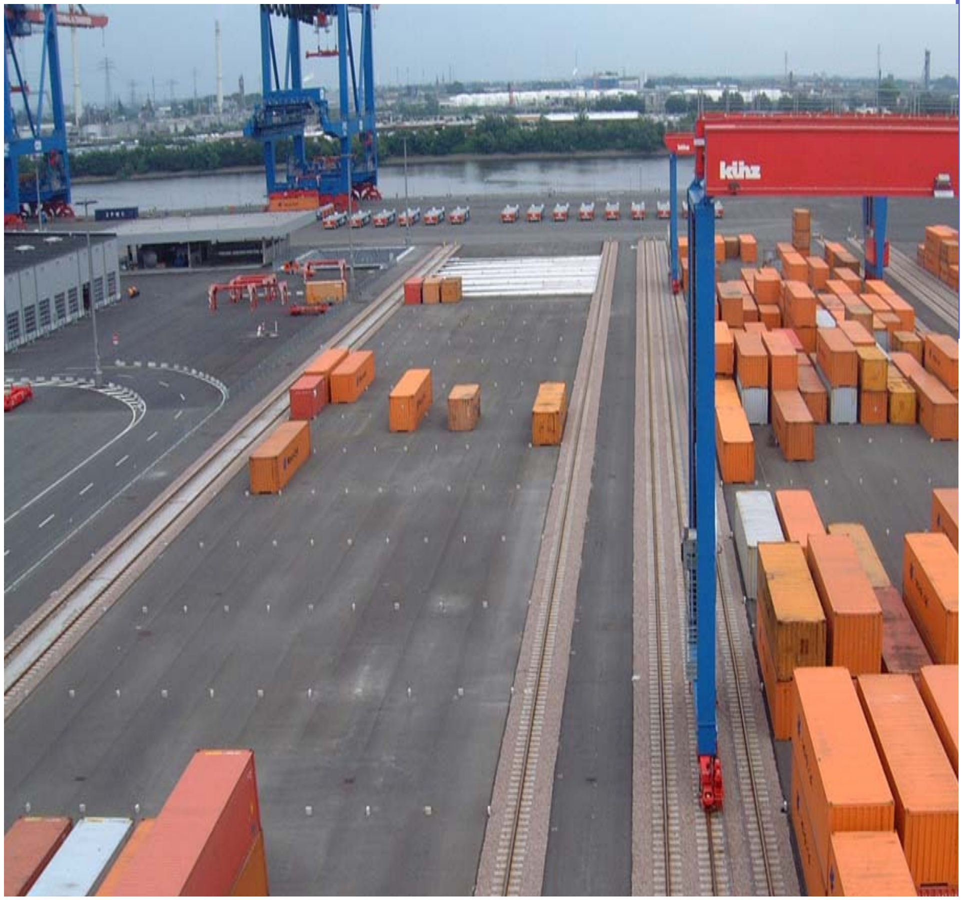


Set down – redo landing if necessary

Solution for very demanding yard/rail conditions

- **TPS**
- **Ground markers**

Used to determine the position of the first container



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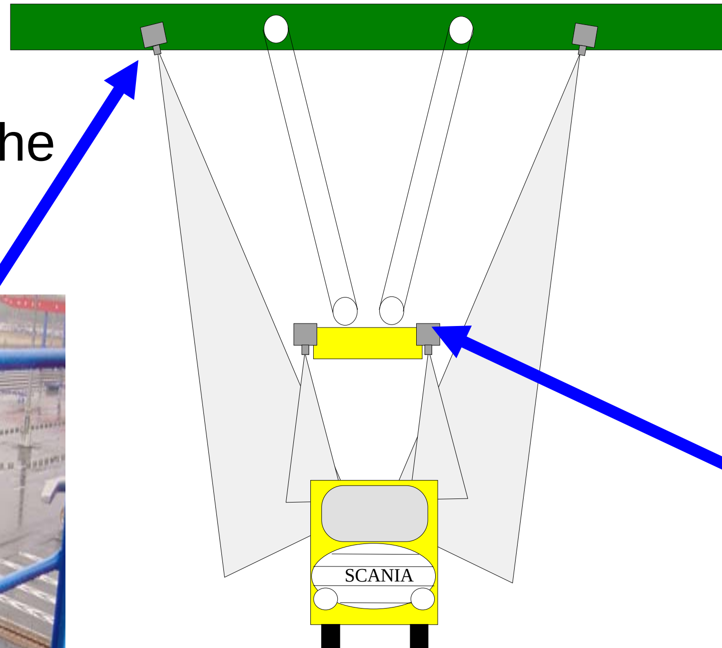
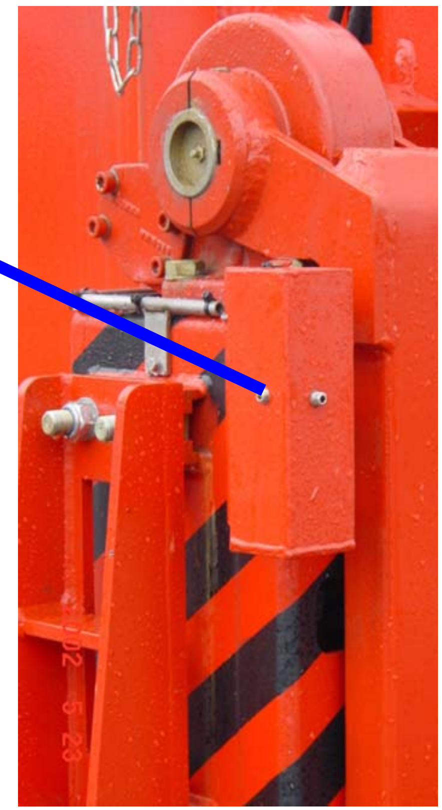
Remote Control – Cameras On Crane



Fixed cameras on the trolley

Four fixed cameras on the spreader



Remote Control

- Good, office style working environment
- Adjustable seat and control desk
- Remote operator can sit or stand

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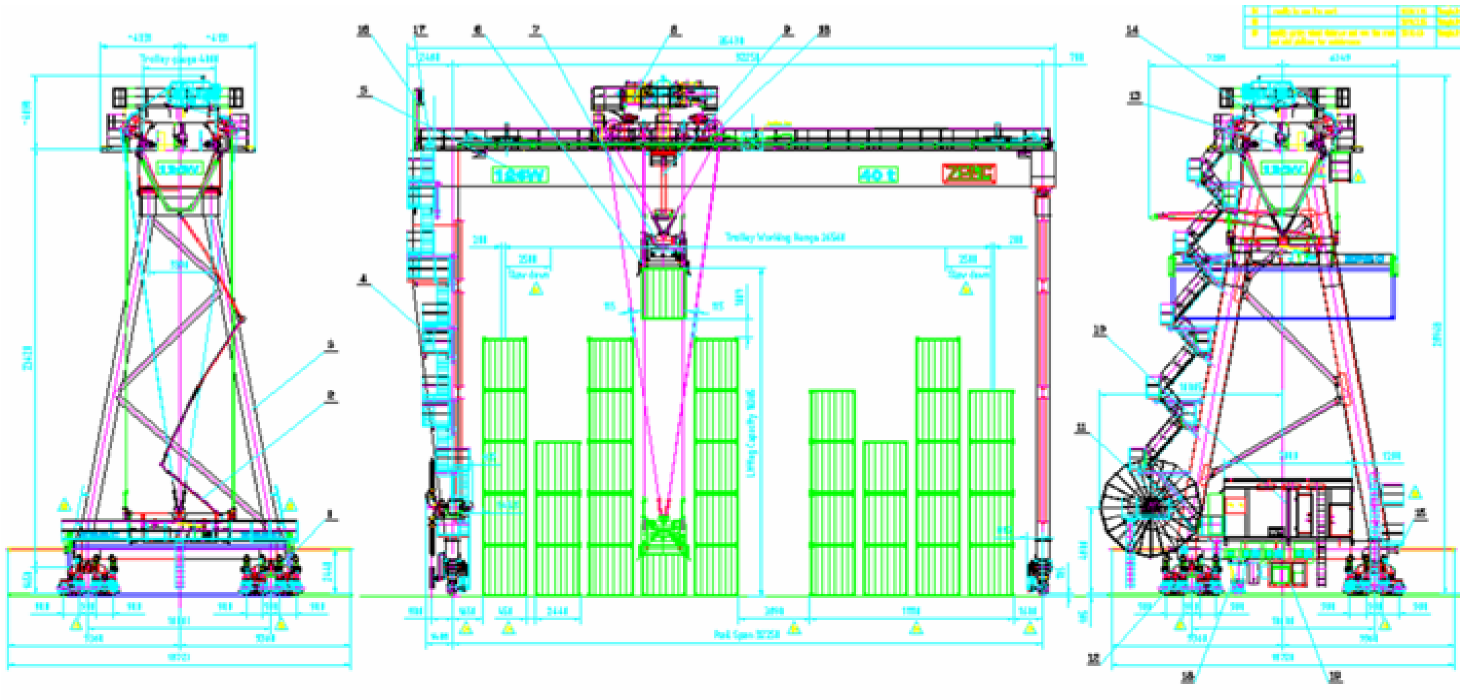
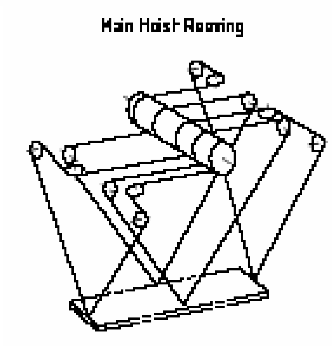
EUROMAX - ARMG (ZPMC)

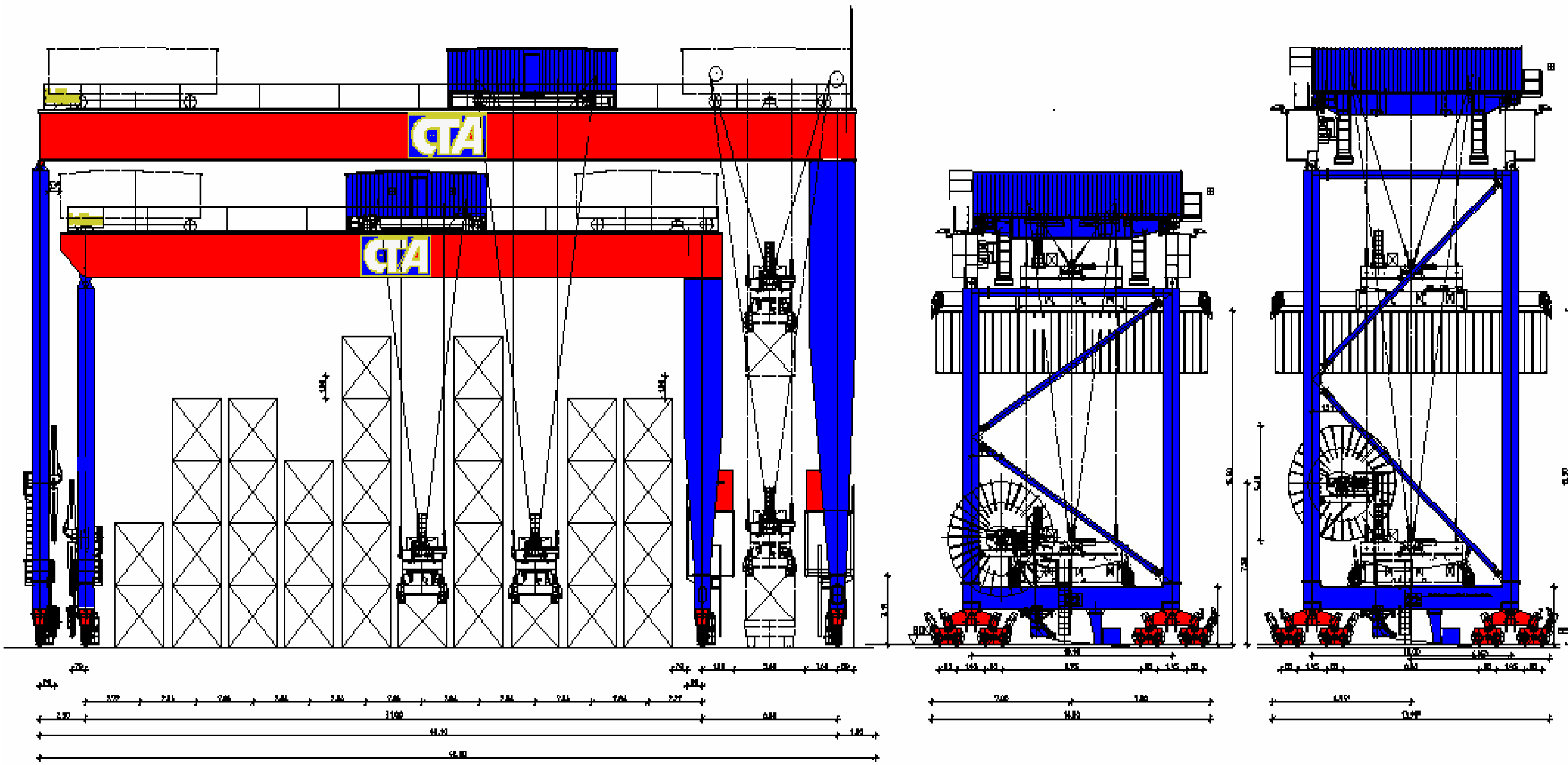




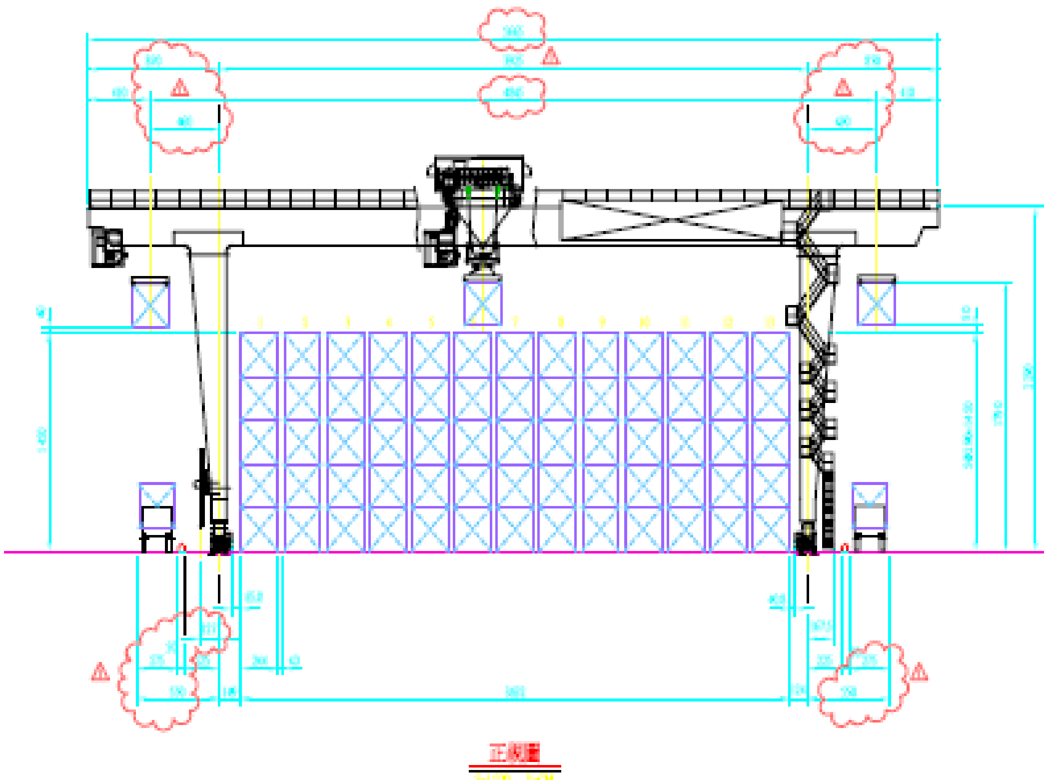
rope tower
rail gauge 32,3 m
lifting height 18,1 m

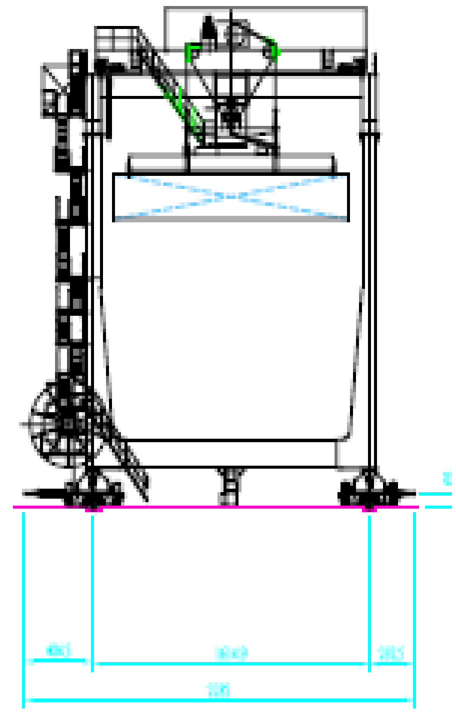
gantry 4,5 m/s
trolley 1 m/s
hoist 1,5 m/s

CTA - ARMG block (Künz,Austria)

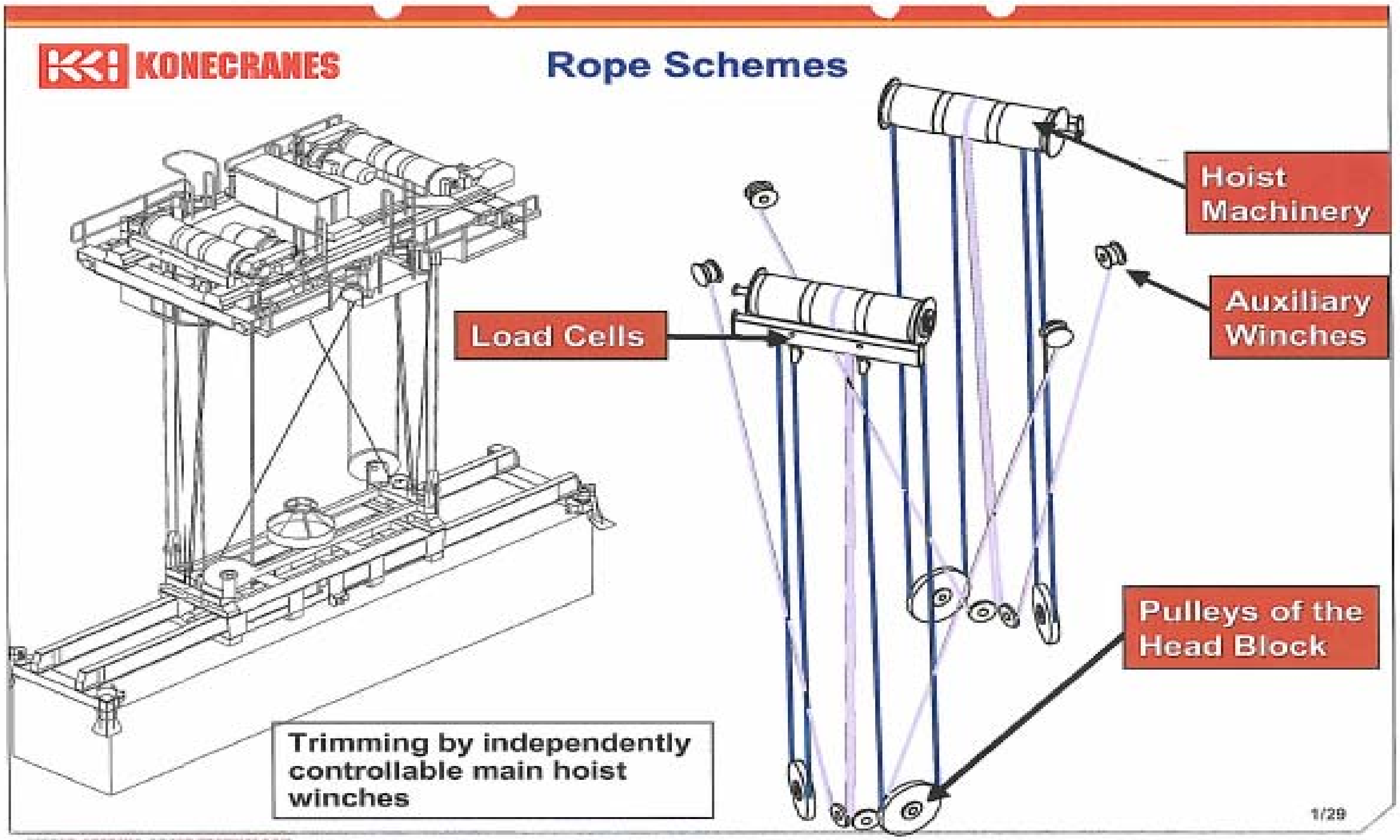


Taiwan – auto CRMG (ZPMC and local crane mfg)





US/Kone – reeving and micro-motion



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Mechanical crane designs for automation

- Width 8 – 13 containers
- Height 4 – 8 - “ –
- Single beam & double – beam
- Weight : 170 – 390 tons
- Hinged /fixed leg & fixed legs only
- Gantry wheels : 8 - 16
- Gantry speeds up to 1000 feet/min (5 m/s)
- Rope reeving : rope tower / straight ropes with sheaves
- Micro – motion : hydraulic/electric/auxiliary ropes
- Front / side loading

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Stacking

- Stacks are built to a vertical reference
- Container position should be checked after each landing. Effects of leaning ground to be handled.
- Minimum distance between the stacks is affected by:
  - Accuracy of the first container placement
  - Size of cameras and guides on spreader

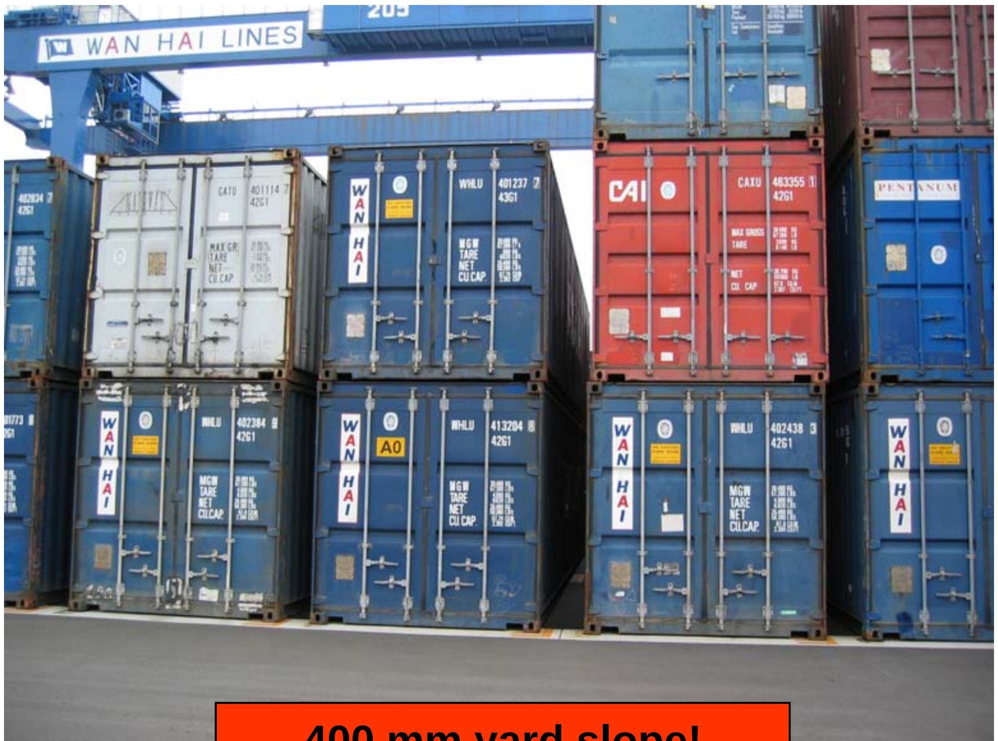
Typical distance between stacks is 14- 18''.

(350 – 450 mm) – trade off with cycle time.

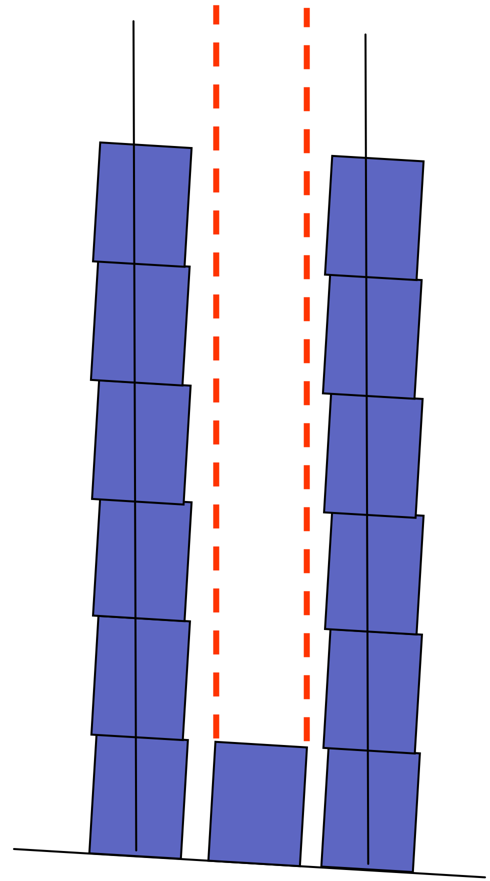
Automatic stacking better than manual.

Staggered stacking

Yard slope up to about 1,0 %



400 mm yard slope!



Ground conditions - the rail challenge

Test track in CTA for performance test !

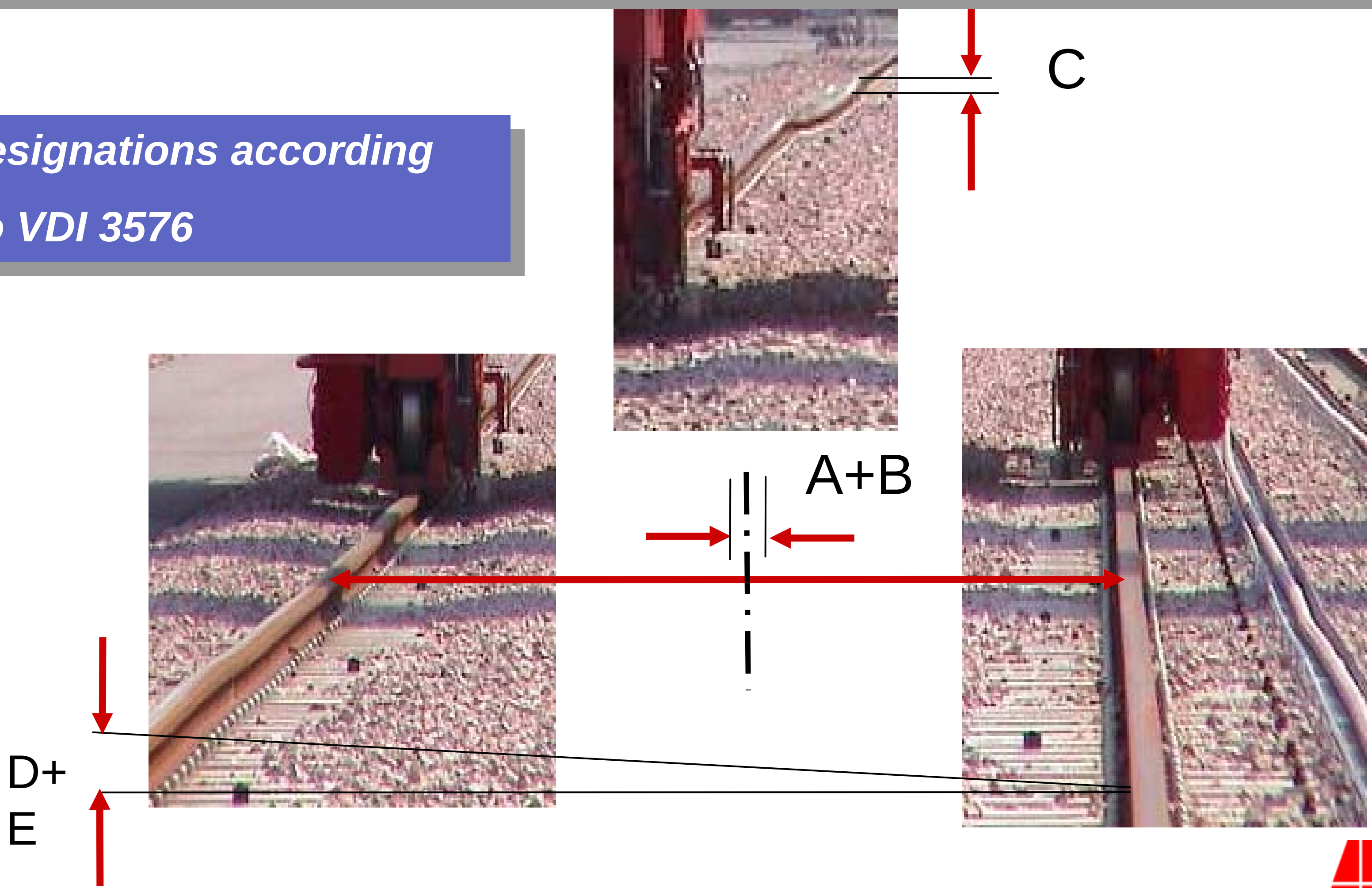
Yard Preparation – CTA experiences

- Due to land-fill in the yard difficult soil conditions were expected
  - **Simple and adjustable rail + sleeper design employed**
  - **Much larger tolerances than typical in “land moving” direction specified (5 – 10X)**
  - **The RMGs were tested on rails prepared with max specified geometry**
  - **Worst conditions due to that the two RMGs operate on different rail tracks (span 31 & 40,1 m)**
  - **Specified function made possible by forgiving RMG design**
  - **No piling required!**

Yard Preparation – Test in CTA 2002

Rails located at maximum allowable tolerances for testing purposes

Designations according to VDI 3576



Technical Data – Rail Tolerances

	CTA - Tolerances	VDI 3567
Track gauge centre	A = +/- (5+0,25 * (s-15) mm	(3+0,25 * (s-15) mm
Position of rail in ground plan	B = +/- 10 mm b = 1 mm	+/- 5 mm
Height of the rail (axial slope)	C = +/- 100 mm c = 50 mm	+/-10 mm c = 2 mm
Height of the rail to each other (lateral slope)	Dmax = +/- 100 mm	+/-10 mm
Inclination of the rails to each other (converging)	E = +/- 1%	0,5%

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CTA, Hamburg – Truck interface

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CTA, Hamburg – AGV interface

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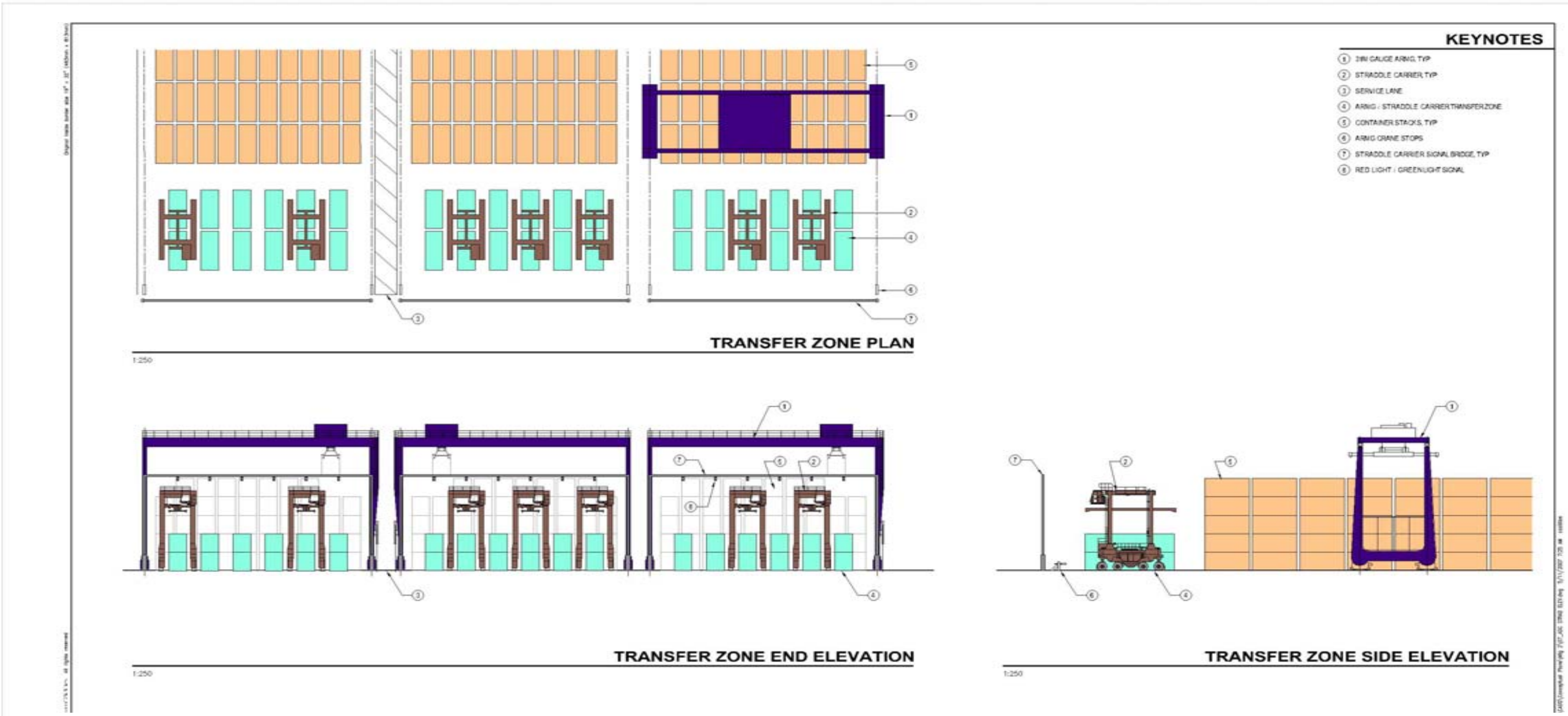
Transfer Zone (TZ)



Interface to vehicles

- **AGVs – fully automatic**
- **Shuttle carriers – fully automatic**
- **Internal tractors/chassis – fully automatic with supervision**
- **Road trucks – manual set-down/pick-up via cameras**

Positioning requirements:

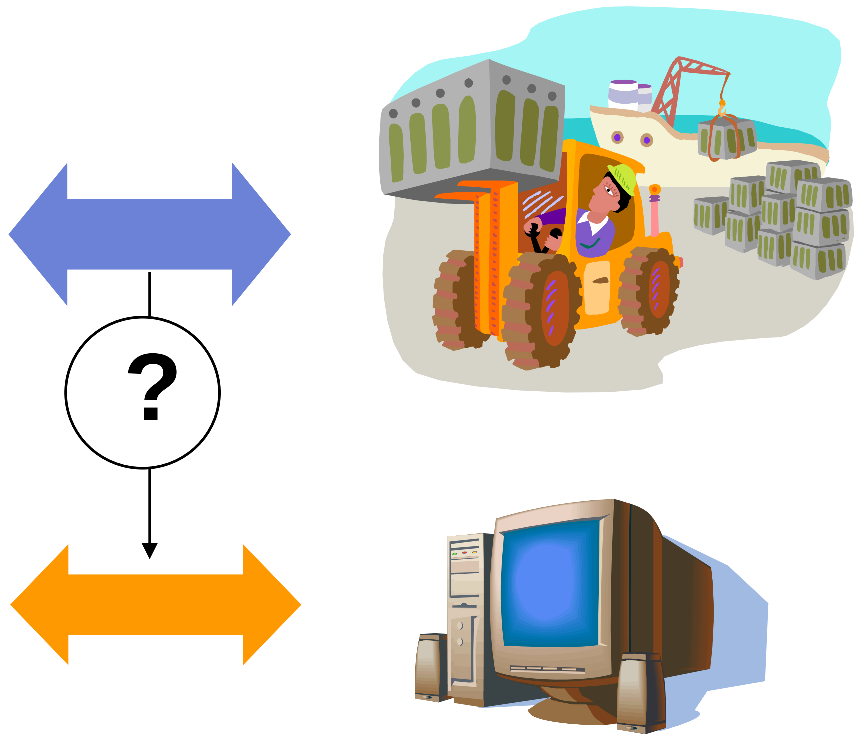
Front - loading

- **Within lane**

Side – loading

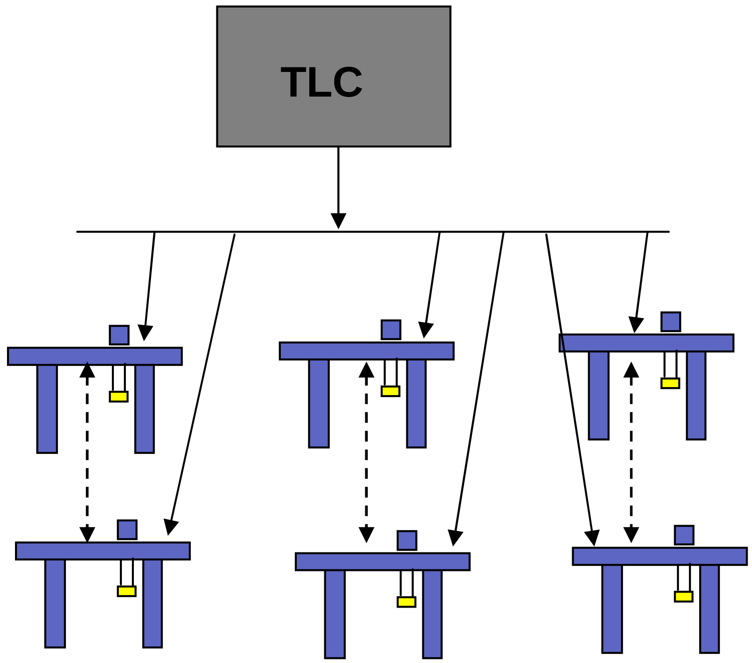
- **+/- 200 mm for min cycle time**

Communication



TLC <-> automatic RMG

- Work order received by the crane
- Crane automatically moves to the target destination
- After work order is completed a job performed message is sent
- Block modification message
- Status message triggered on predefined events



Task division TLC/RMG

	TLC	RMG
Decide container location in stack	X	
Issue work-order	X	
Confirm work-order		X
Calculate optimal path		X
Control crane movements		X
Confirm stack profile		X
Confirm storage conditions		X
Crane-crane optimization	X	
Crane-crane collision avoidance		X
Confirm container location		X
Report work-order finalized		X
Up-date block map	X	X
Request manual intervention		X

Topics

Requirements on crane design I

- **Precise positioning systems**

-> to minimize cycle time

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- **Possibility to accommodate for changing geometry**

-> to work with the forces of nature

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- **Precise positioning systems**

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- **Possibility to accommodate for changing geometry**

-> to work with the forces of nature

- **Mechanically robust**

- > to allow operation in high winds

Requirements on crane design I

- Precise positioning systems

-> to minimize cycle time

- Possibility to accommodate for changing geometry

-> to work with the forces of nature

- Mechanically robust

- > to allow operation in high winds

- High quality

-> to facilitate a high availability

Requirements on crane design II

- **Proper installation**

- > no unexpected disturbances

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- **Efficient Crane Management System (CMS)**

- > no driver on the crane

Requirements on crane design II

- Proper installation

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- Efficient Crane Management System (CMS)

- > no driver on the crane

- Possibility to handle work orders from TOS/TLC

- > to ensure a high productivity

Requirements on crane design II

- Proper installation

- > no unexpected disturbances

- Efficient Crane Management System (CMS)

- > no driver on the crane

- Possibility to handle work orders from TOS/TLC

- > to ensure a high productivity

- Proper camera surveillance system

-> to minimize time for manual operation

Conclusion

- **Automated crane designs exist that can fit basically any type of terminal (lay-out, operational mode, etc)**
- **The challenge is the systematic approach required (planning, exception handling etc)**
- **The cooperation auto RMG and TLC/TOS is vital**
- **The automation concept must be able to handle unexpected conditions, rails, yard, wheather etc**

ABB

Power and productivity
for a better world™