Optically jointed probing systems for large volume coordinate metrology

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Concepts presentation

- "Walk around" probing is here but does it do enough?
  - Leica T-System, API Intelliprobe, Metris K-Scan and iGPS, Metronor Solo ..
- This concepts presentation visualizes metrology systems which:
  - Reduce the need for direct visibility to the feature point
  - Provide a deeper reach into measured objects
  - Offer scope for automation and integration into a manufacturing environment
- Concepts mostly take forward, combine or extend existing ideas
- The first part of the presentation looks at full systems
- The second part examines some possible detailed components
- **Feedback on potential applications is welcomed!**

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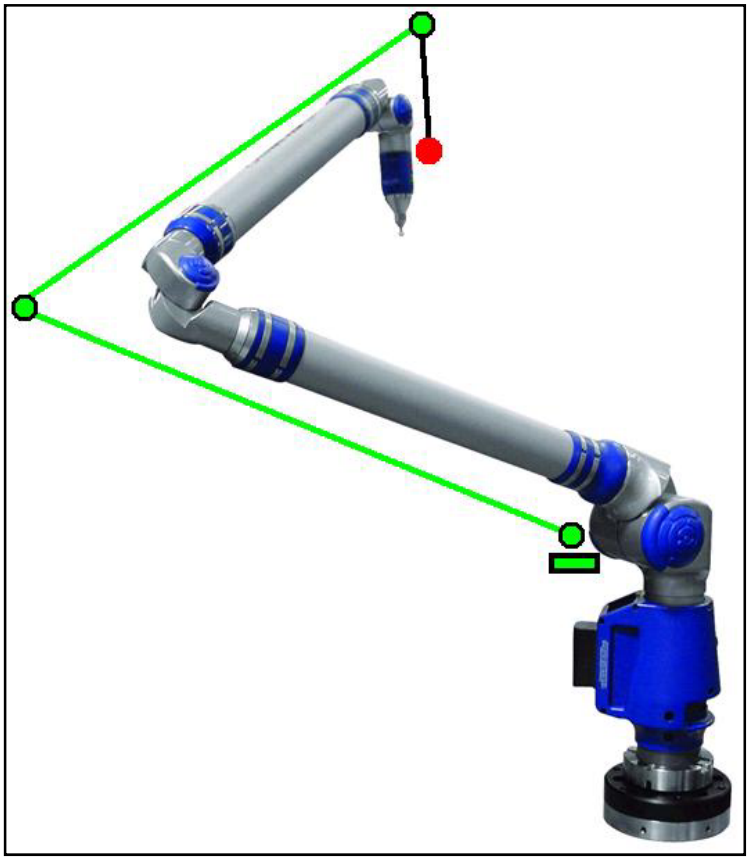
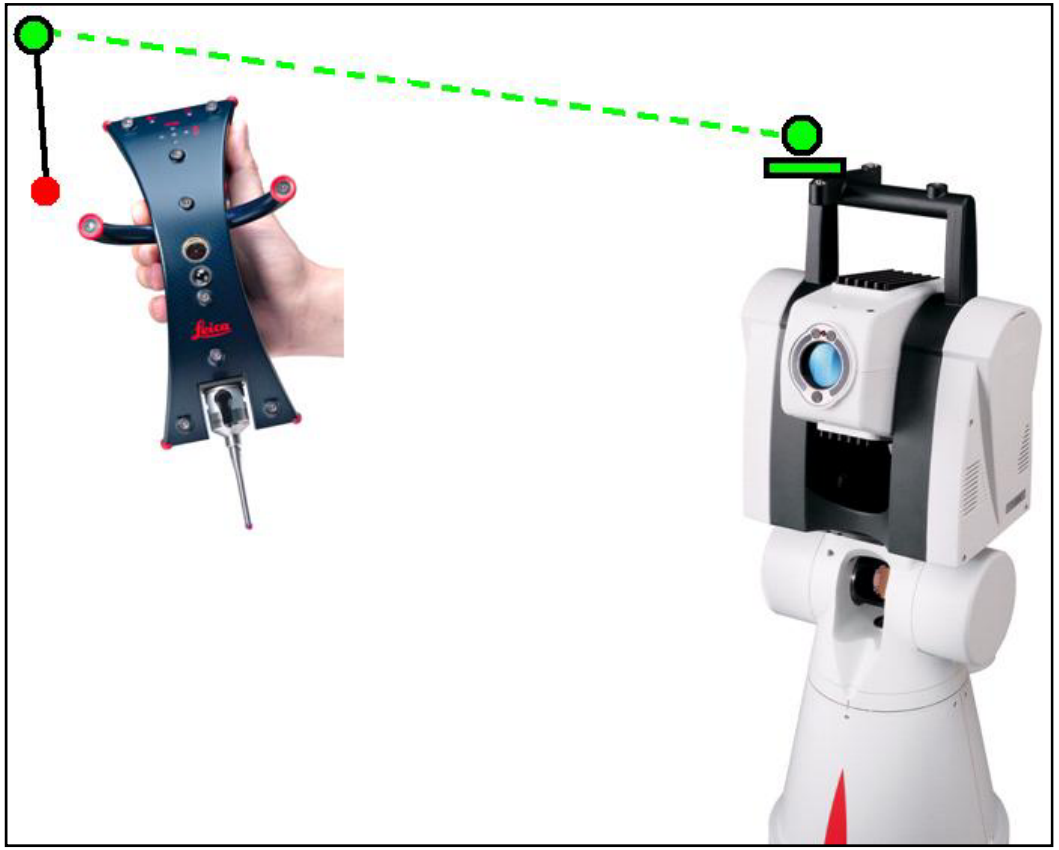
Access hidden points: reach around corners





- Joints in the fixed link arm enable probing around corners
- A typical "walk-around" system (example: Leica) is equivalent to an arm with one less joint, one variable length link and a (relatively) short link to the probing point

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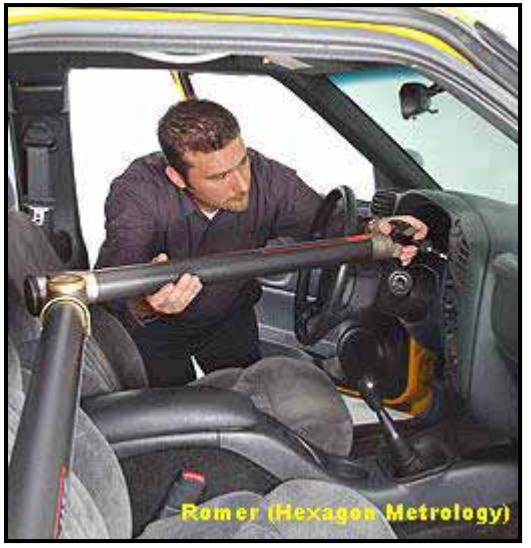
Working in and around objects – some issues



- Probes on optically linked systems (e.g. Leica, Metris) are potentially easier to handle in confined spaces
- Arms (e.g. Romer) have deeper reach, potentially better for larger objects such as aircraft components
- Trackers have panoramic view, hence large working volume, camera systems have directionally restricted volumes
- In contrast to tracker probes, camera probes can adopt almost any rotation and are particularly robust to viewing interruptions

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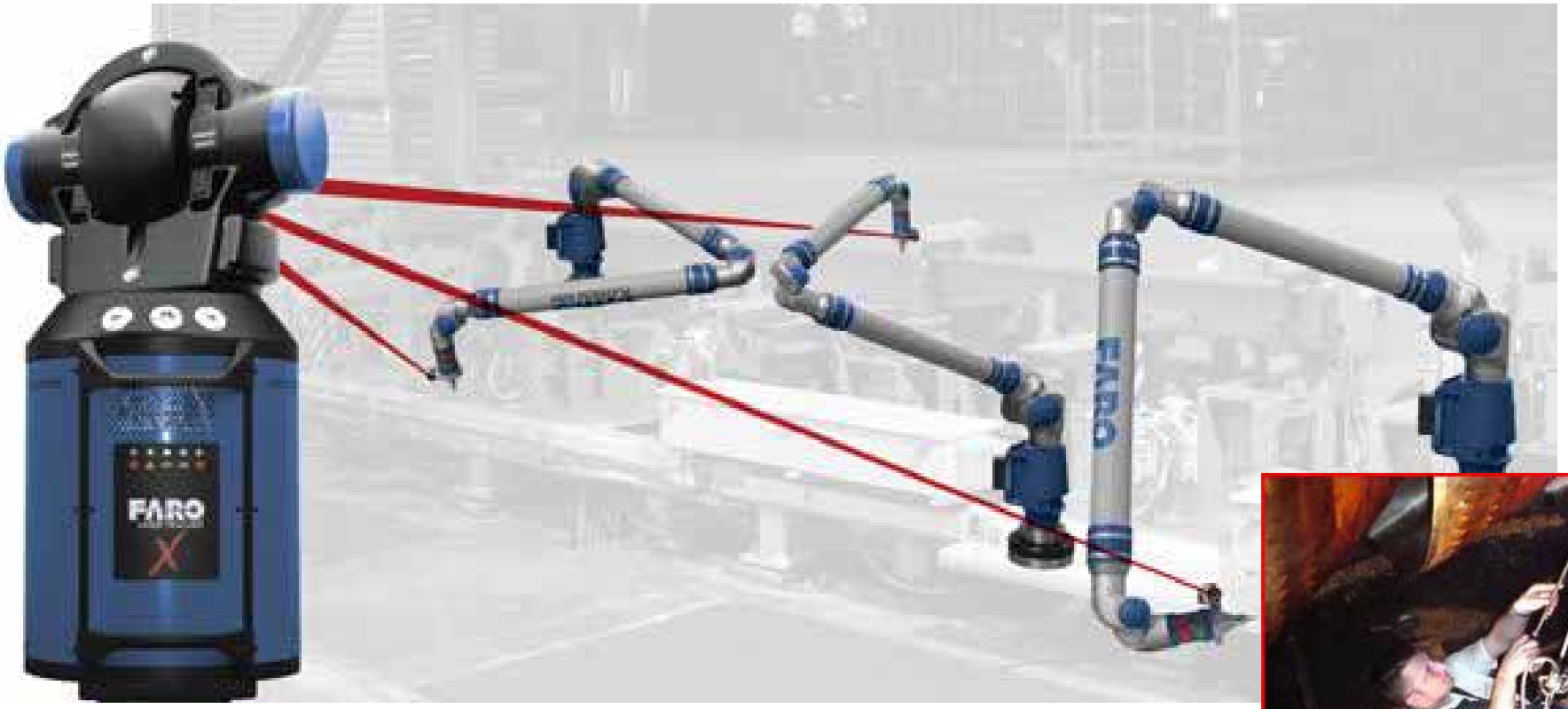
FARO TrackArm – deep reach, large volume



- Deeper reach than hand-held probes
- 2-stage set-up – not a "walk-around" solution
  - No real-time monitoring of the probe
  - Unstable platforms not possible, e.g. mobile tripod, manlift
  - Difficult situations exist, see Romer turbine blade measurement (inset photo)
- Not (yet) an automated solution

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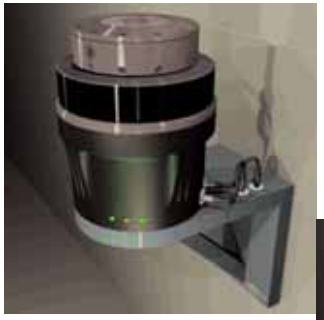
Real-time (robot) arm tracking with iGPS?



- iGPS positioning of a CMM arm already demonstrated at previous CMSC
- Could Metris use the newest version of iGPS to drive their new robot arm for a fully automated, large volume metrology system?

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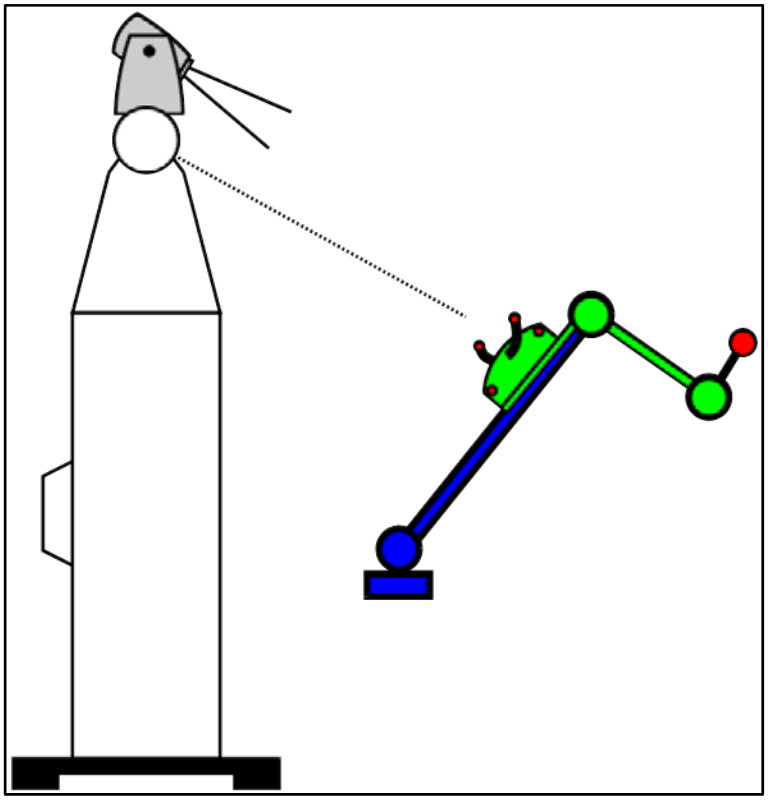
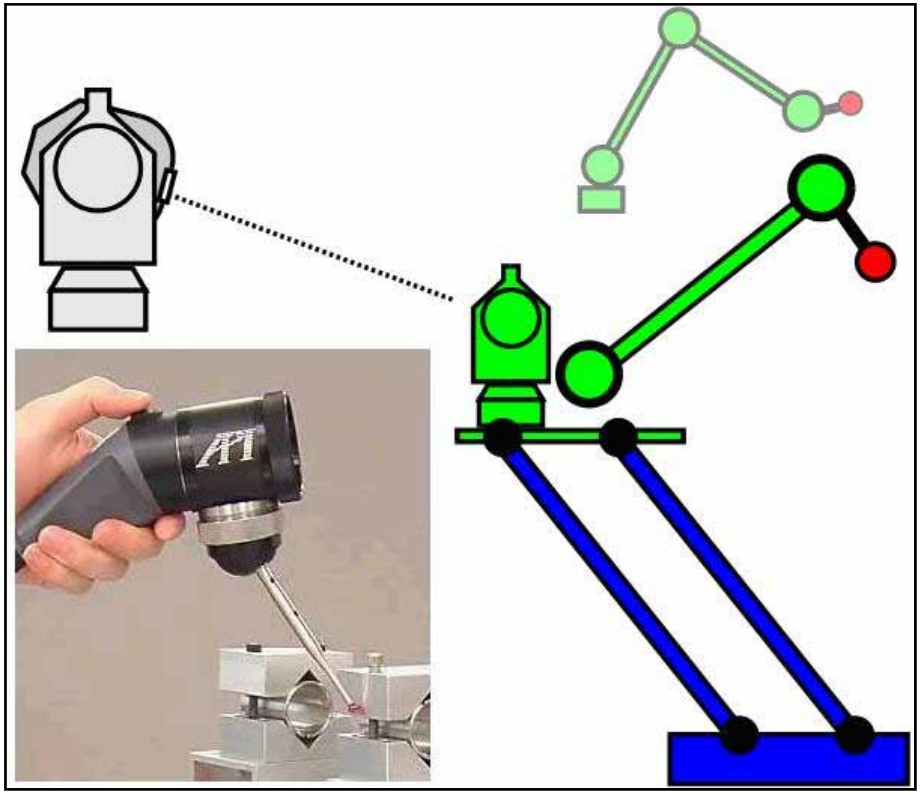
Alternative "TrackArm" designs?





- Leica T-Mac on a manual or motorized arm
  - Needs a wider acceptance angle at reflector? (N2 sphere, dynamic target switching?)
- API SmartTrack on a mobile arm platform – motorized pan, tilt and roll
  - Good horizontal and vertical link, platform handles restricted roll
  - A "big brother" version of the hand-held device (photo)

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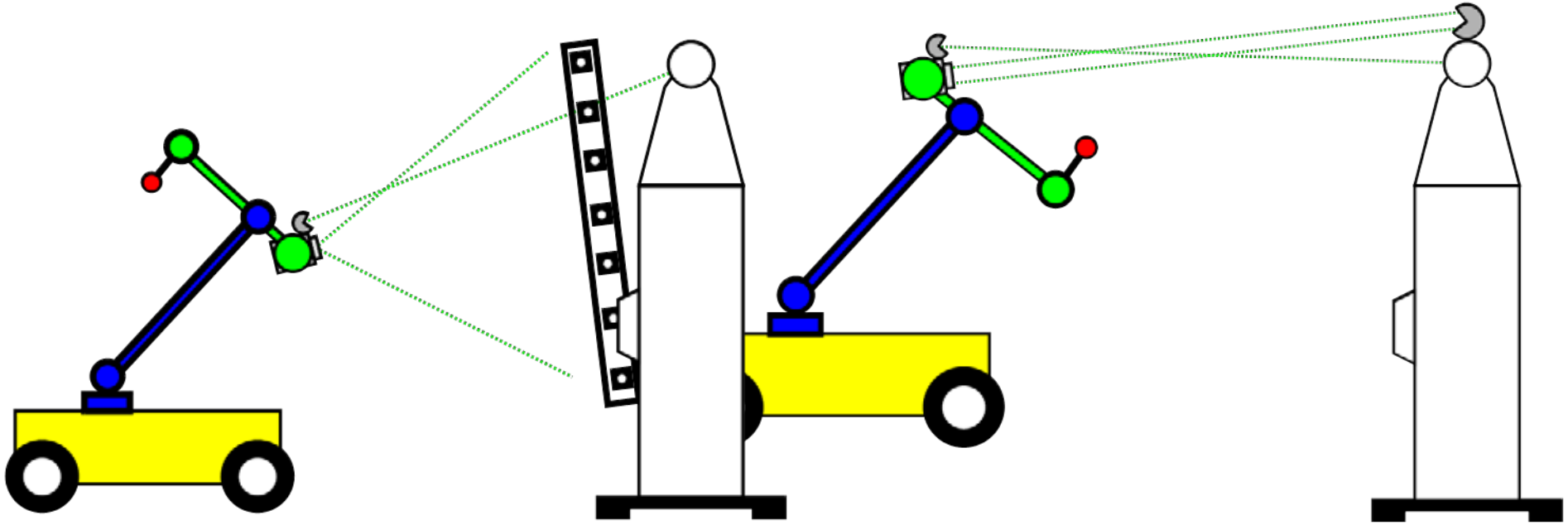
Motorized pan&tilt target + full roll detection



- Full roll enables greater flexibility in TrackArm design
- Concept on left has a motor-driven, tracked camera which views multiple reference targets (Metronor patent application).
  - Could work at short range with tracking theodolite only (Kyle, CMSC05)
- Concept on right finds roll from laser beam retro-reflection (details later)
- Target arms could potentially be developed independently of trackers
- Scope for mechanizing/automating

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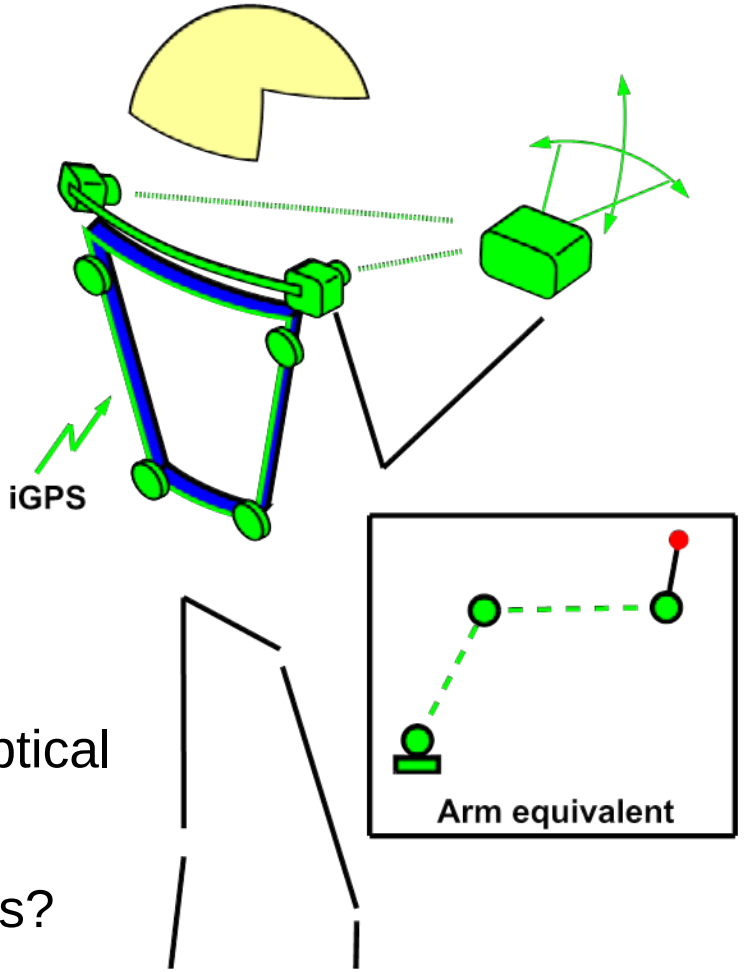
Cascaded optical tracking systems



- Cascaded tracking adds a second joint for a fully optical version of a mechanical arm with a moving "elbow"
- Easier to use than concepts incorporating fixed links?
- Move the elbow under computer control to optimize the link from fixed base to probing point?

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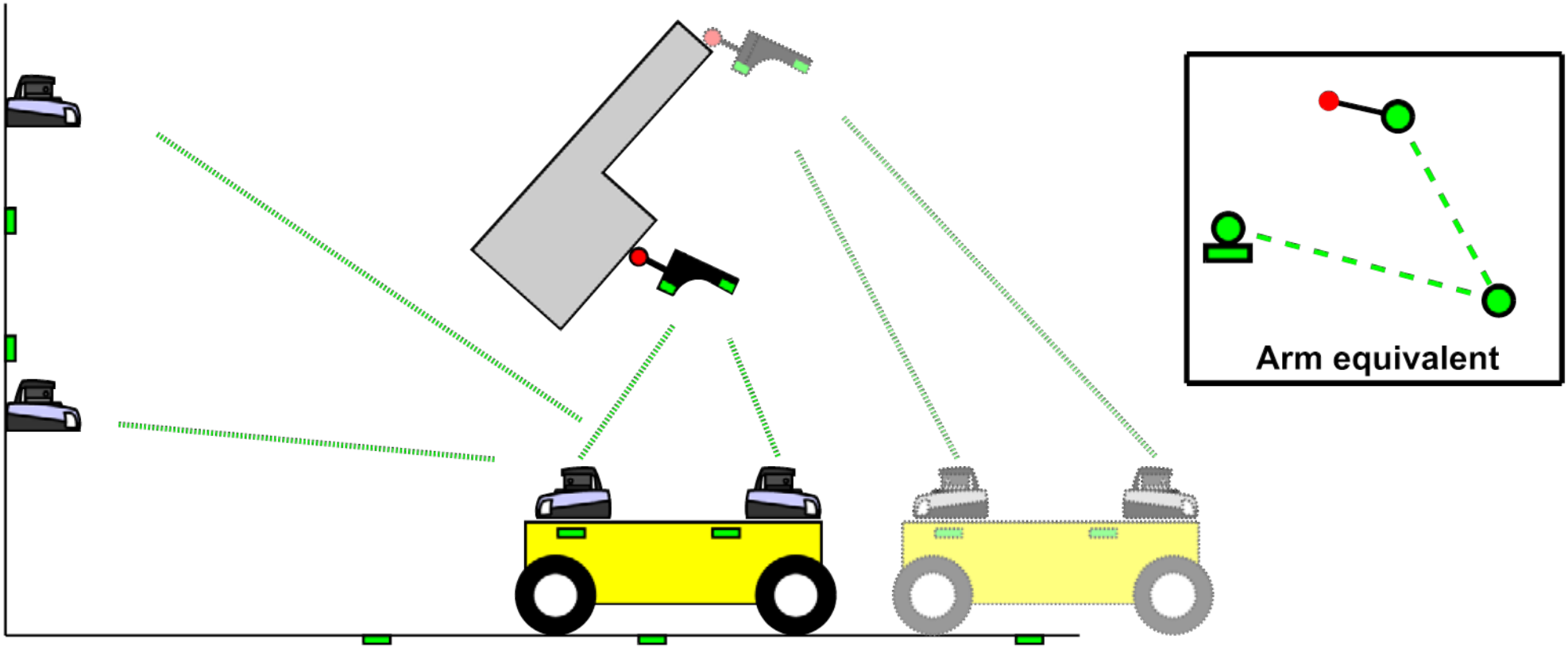
Dynamic network configuration for iGPS



- iGPS extends coverage by adding more fixed transmitters
- Alternatively, extend the "moving elbow" concept to a dynamic network of iGPS transmitters, some fixed, some moving as required?
- Map the current dead areas and re-configure as required to optimize the current measurement needs?

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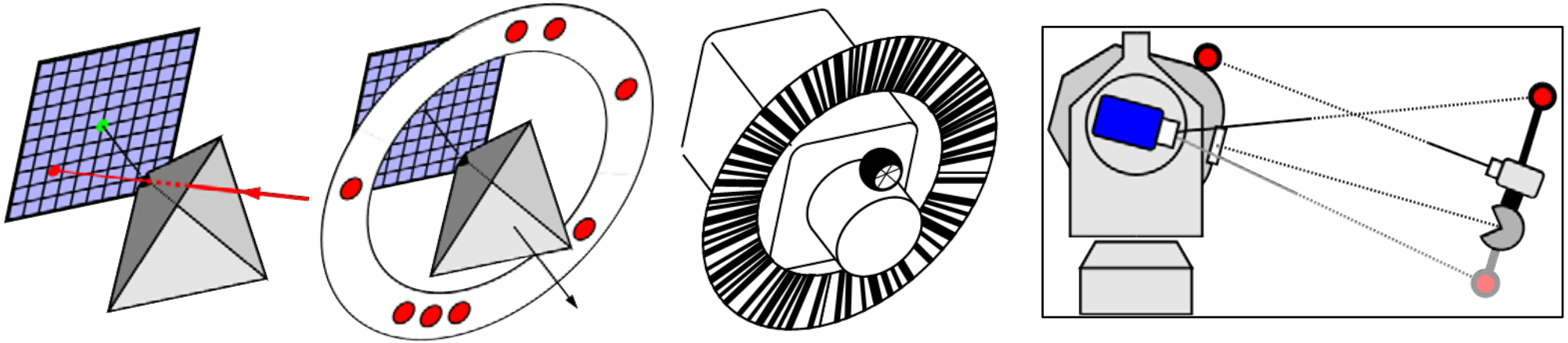
Design details – 6DOF joints for trackers



- Joints in the optically linked probing systems are 6DOF connections
- For laser trackers, pan&tilt targets have wide acceptance angles and work in automated systems. Roll is a critical missing element.
- Pinhole prism on left (Boeing, Leica patents) gives 3D + pan & tilt
- Prism on right, with min. 1 additional target and on-board imaging, also gives roll
- Pan and tilt also possible using camera, here with optimized coded roll target

- Diagram on left shows possible implementation in full system
- Mostly external add-ons required
- Potential option to make laser scanner act as a tracker?

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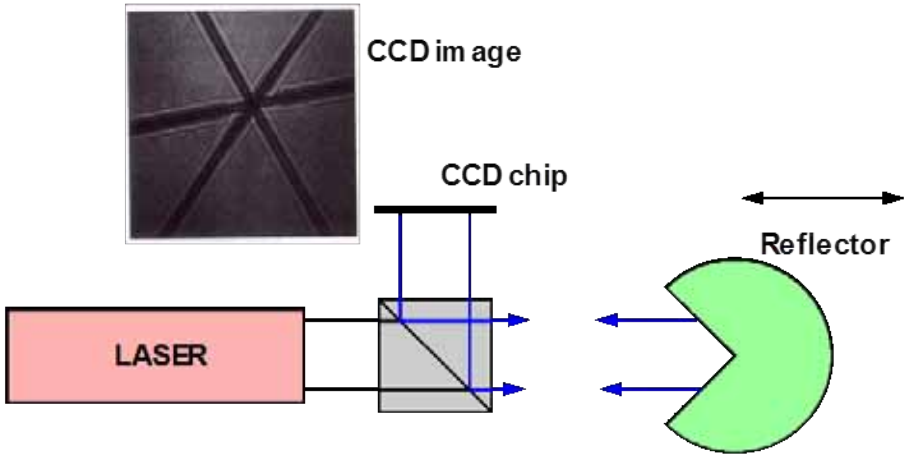
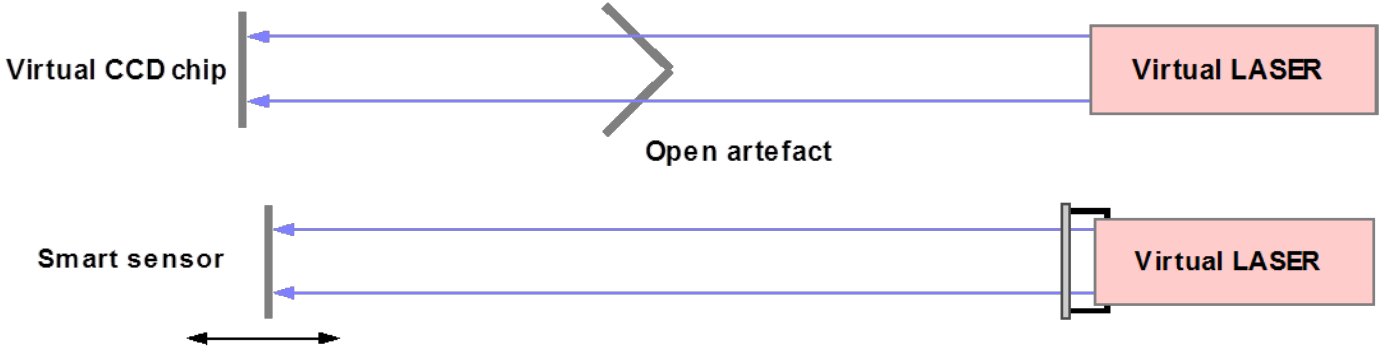
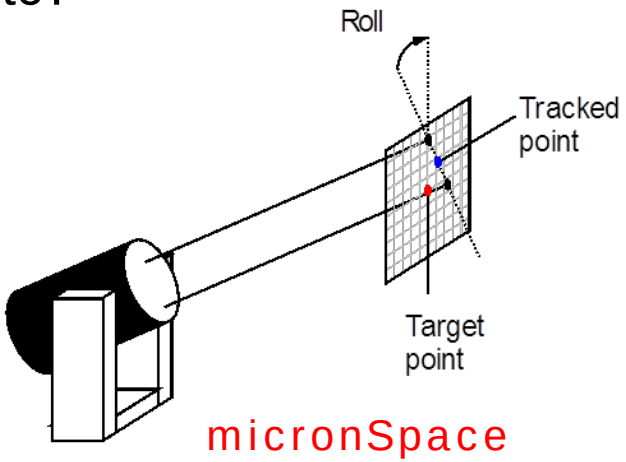
Roll from projected structure/pattern in beam



- Tech. University of Vienna developed 6DOF tracker in 1990s
- Target's angular orientation from back-projected shadow image of reflector edges
- Concept here extracts the roll element only
- Target mask on laser tracker beam, e.g. 2 dots, projects shadow or interference pattern onto target CCD image, hence roll of beam
- Problems due to imperfections in optics, range limitations, etc?





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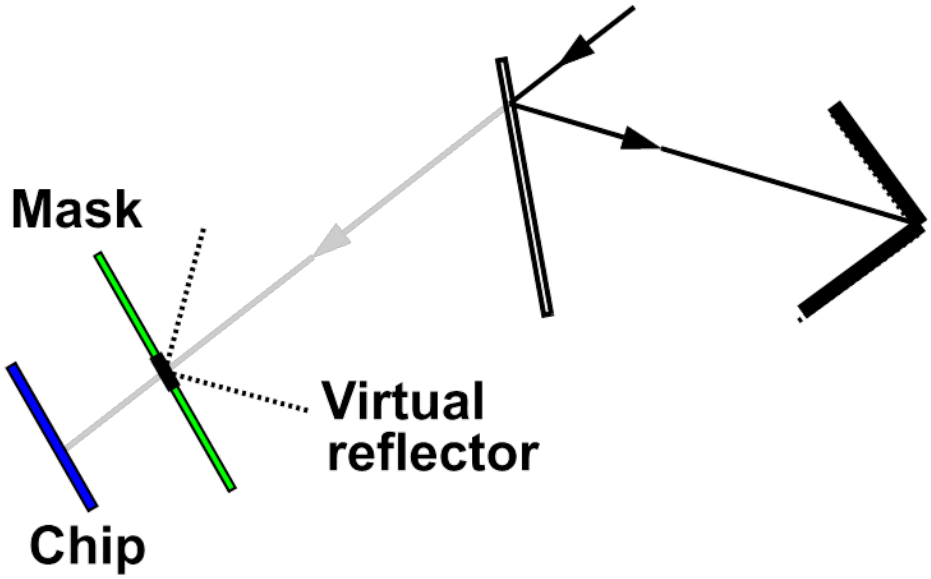
Adding pan and tilt to projected roll angle



- One concept resembles mini version of Faro retro probe (or Leica surface probe)
- Partially reflecting mirror takes part of beam through a mask at the reflector's virtual image
- The mask, e.g. opaque dot, is projected onto a CCD chip. Like an inverse pinhole, the xy chip location of the dot is a measure of pitch and yaw
- Roll is detected from remaining structure, inserted at source and projected with the beam

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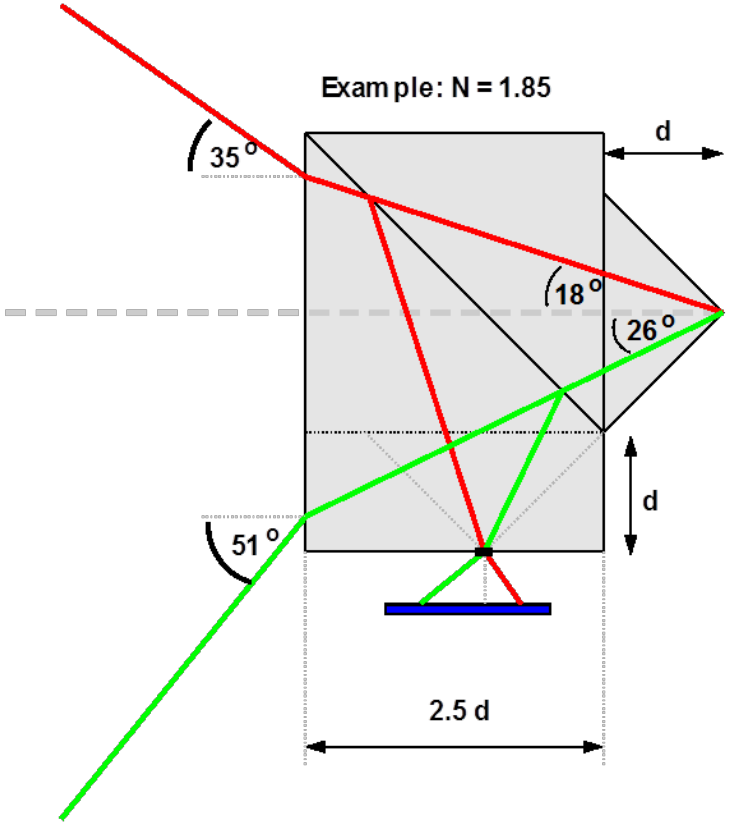
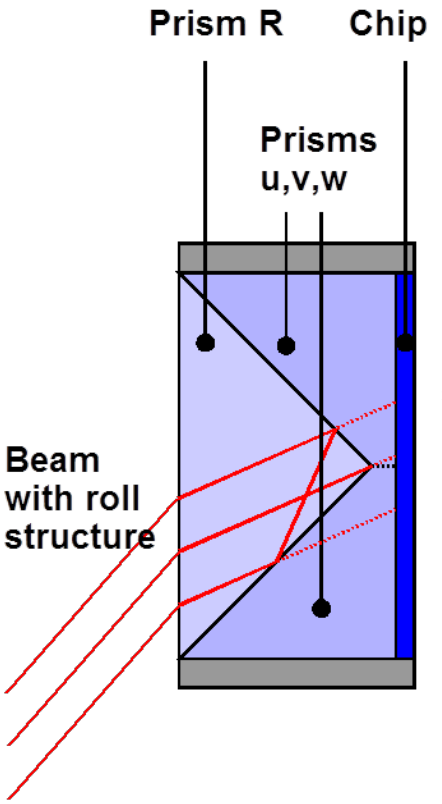
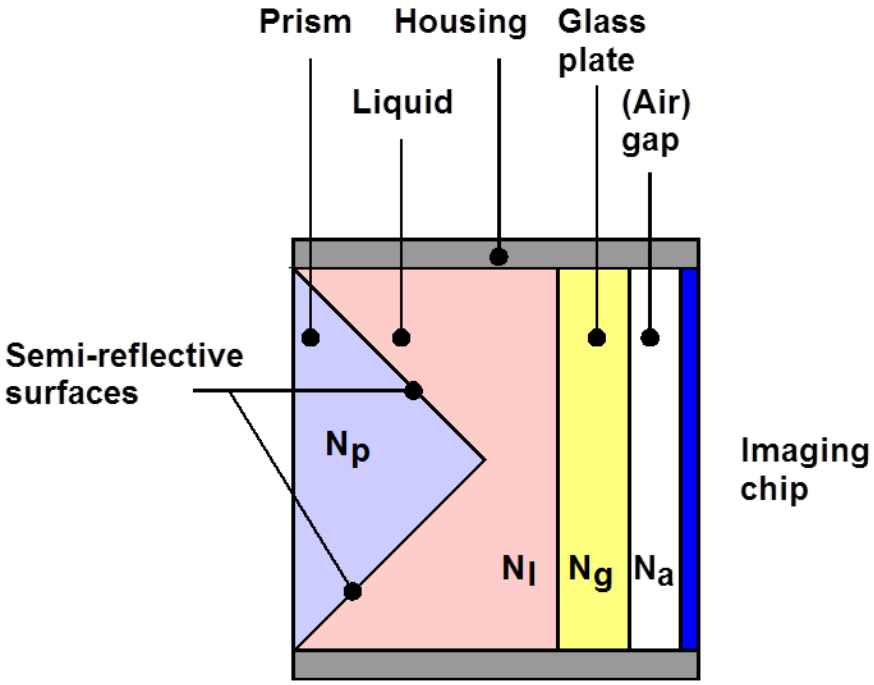
Alternative beam-splitting prism reflectors







- An alternative way of including semi-reflection in a prism is shown on the left, effectively a cube beam splitter attached to the front of a normal prism reflector
- The middle diagram shows a more compact version where the prism surfaces are semi-reflective and mate with prisms having the same refractive index
- A more practical version with a liquid interface is on the right

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Conclusions

- This presentation is intended to stimulate discussion on future large volume metrology systems and encourage their development
- Not all concepts are necessarily workable in practice but they can provide alternative ideas which lead to other more practical solutions
- All designs require further simulation and analysis, particularly regarding potential accuracy
- A deeper reach and multiple connections require accurate link lengths and, more critically, higher angular orientation accuracy at the joints
- Development is an iterative process between system designer and end user but ultimately applications determine needs and drive the future
- **Feedback on application requirements is very welcome**

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