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Optimised Multi-Dimensional Image Scanning With RASCAN

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Synchrotron X-ray Fluorescence Microscopy

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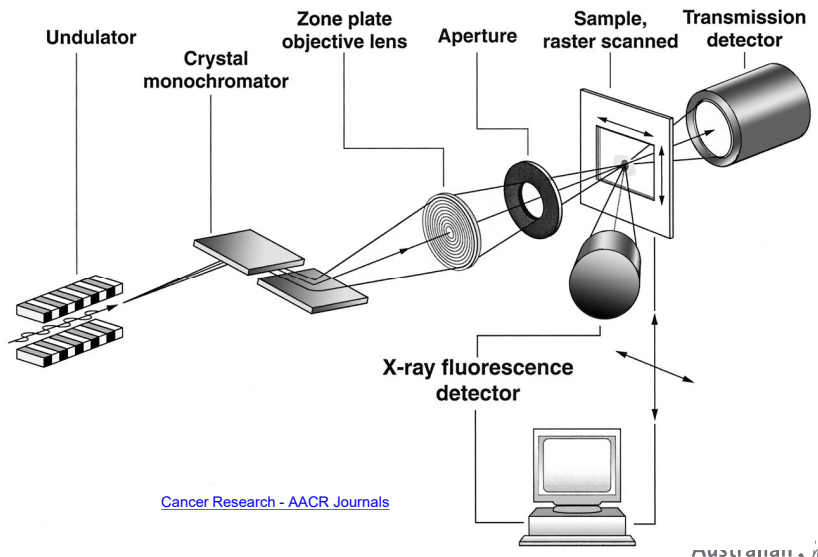

Cancer Research - AACR Journals

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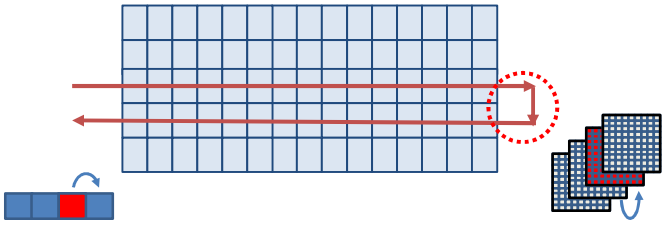
Scanning Microscopy: Overheads



	~~Pixel by Pixel~~	Line by Line (1000 pixels)	3rd dimension (eg: angle, energy)
Typical dwell	~~1 ms~~	**1000 ms**	**1000 s** (1000 Lines)
Motion Overhead	~~150 ms typical~~	**355 ms** @ XFM	**2 s + 355 s**

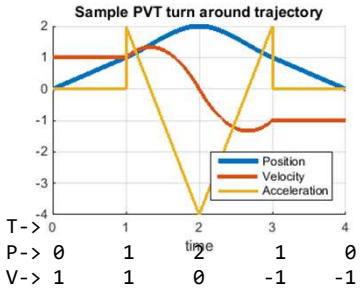
Overheads > 30%

- Detectors have become faster by 3 orders of magnitude
- Science is now limited by motion overheads

nD Fly-scan formulation

- Common approach: Use arbitrary motion trajectories *implemented* as an array of Position-Velocity-Time (PVT) elements **{ Point[1..n],Velocity[1..n],Time[1..n] }**

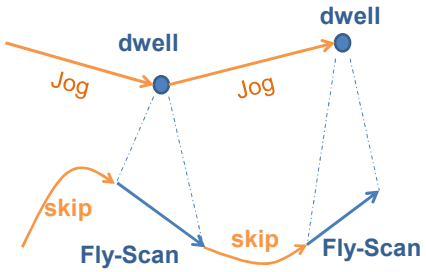
➢ **Setting PVT points is NOT trivial. User application needs to deal with kinematics.**



nD Fly-scan formulation

- Step-scan motion is a sequence of "Dwell at a Point" elements
  { Point[1..n] }, Dwell[1..n]=DwellTime
- Fly-scan motion can be *formulated* as a sequence of "Scan along a Vector" elements
  { Vector[1..n] }, Vel[1..n]=ScanVel

Science request **Overhead motion**



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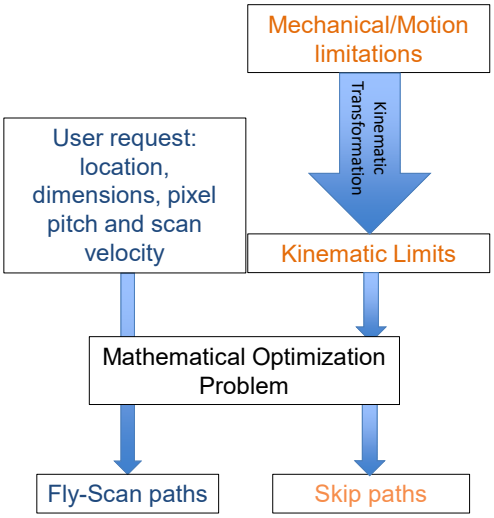
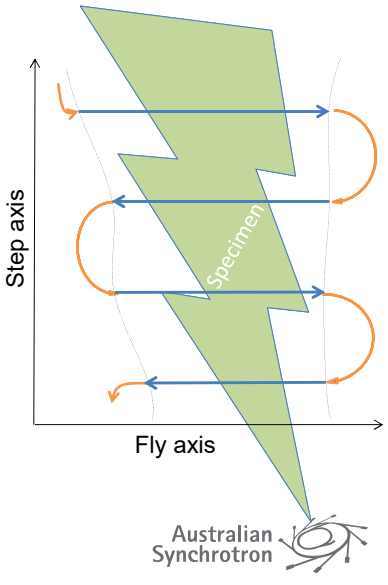
2D Raster Imaging





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RASCAN design

1- Design trajectory: PVT points

2- Solver/Builder: Find the PVTs such that overhead time is minimized.

Given:

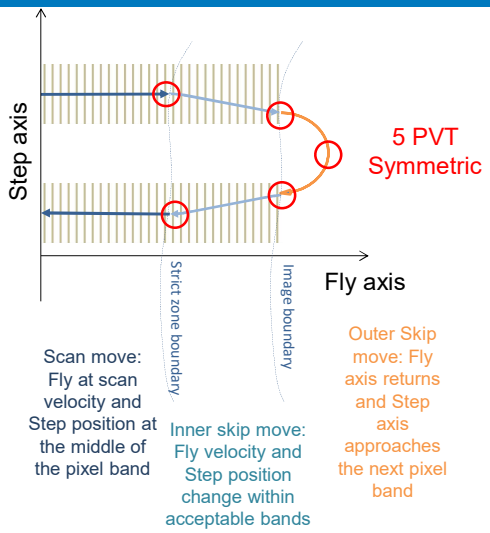
a) **Science** inputs

- **Geometry**
- **Step increment, Scan velocity**
- **Step position band, Scan velocity tolerance**

b) **Motion** limitations, represented by limits for jerk, acceleration, velocity and position

c) **Controller** limitations (e.g. min PVT time)

3- Execute Motion Program: Loop through PVT's for **n steps and width[1..n]**



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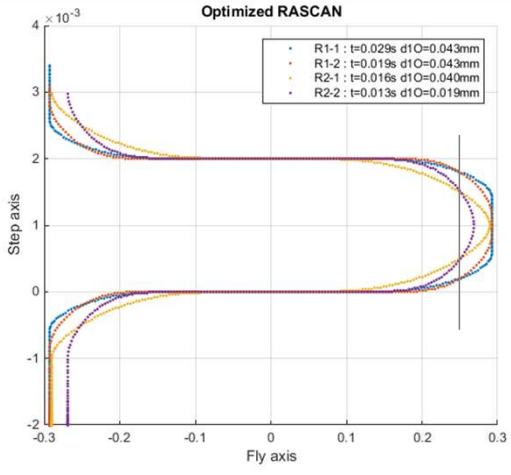
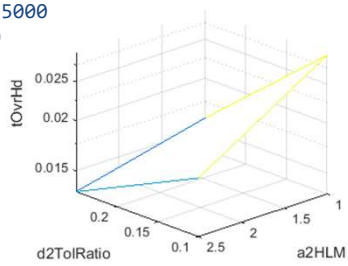
Optimized solutions




```
d2Step=0.0020
v1Scan=4
v1TolRatio=0.8000
d2TolRatio=[0.1,0.25];

a1HLM=500; pE1Res=0.0001;
pE2Res=0.00002;
a2HLM=[1,2.5];

d1Span=0.5000
d2Start=0
nLines=2
```



Naming: Fly-Axis is 1, Step-Axis is 2
Units are mm and sec

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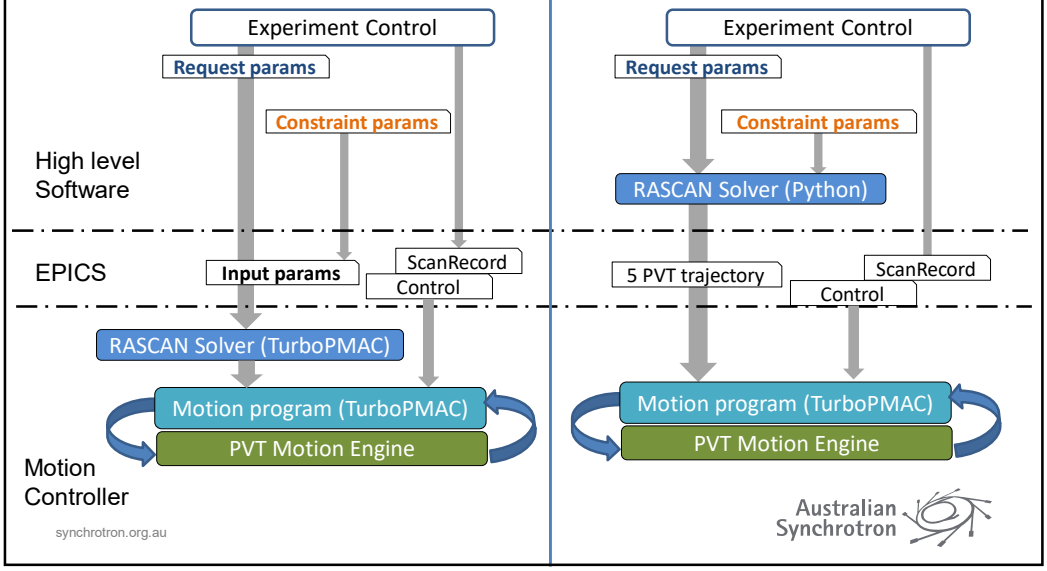
RASCAN Implementation



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RASCAN

EPICS CS Motors | Asyn driver

EPICS Real Motors | CS Kinematic Transforms | Rascan engine

tpmac | tpmac | tpmac

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RASCAN Motion Program

```
while (lineN < lineEnd )
    lineDir = (lineN is even? 1 else -1)

    INC PVT (tOut)      X (lineDir * d1Out): (lineDir * v1Out)    Y (d2Out):(v2In)
    INC PVT (tIn)   X (lineDir * d1In): (lineDir * v1In)   Y (d2In):(0)

    INC PVT ( tMid[ lineN ])  X (lineDir * tMid[ lineN ] * v1Scan):(lineDir * v1Scan ) Y (0):(0)

    INC PVT (tIn)   X (lineDir * d1In): (lineDir * v1Out)      Y (d2In):(v2In)
    INC PVT (tOut)      X (lineDir * d1Out): (0)               Y (d2Out):(v2Out)

    lineN = lineN+1
    ...
endwhile
```

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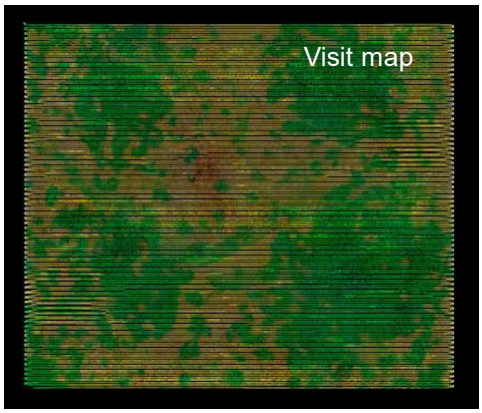
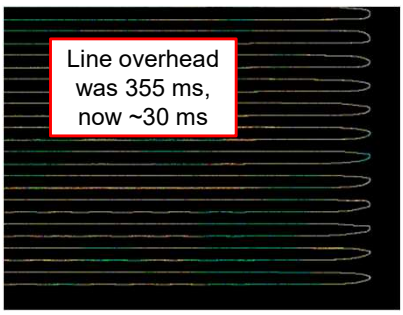
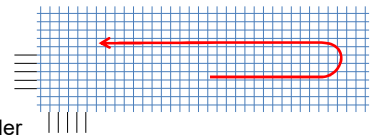
RASCAN 1.0 results at XFM



0.5 mm wide, 4 mm/s, 2x2um, 250 lines

	Line by Line	Rascan
Line O/H	355 ms / line	~30 ms / line
Daily O/H	1-4 hours	10-30 min





Encoder
100nm

Controller: Delta-Tau GeoBrickLV
Implementation: Nader Afshar
Stage design: Walsh, Afshar, LeGuen

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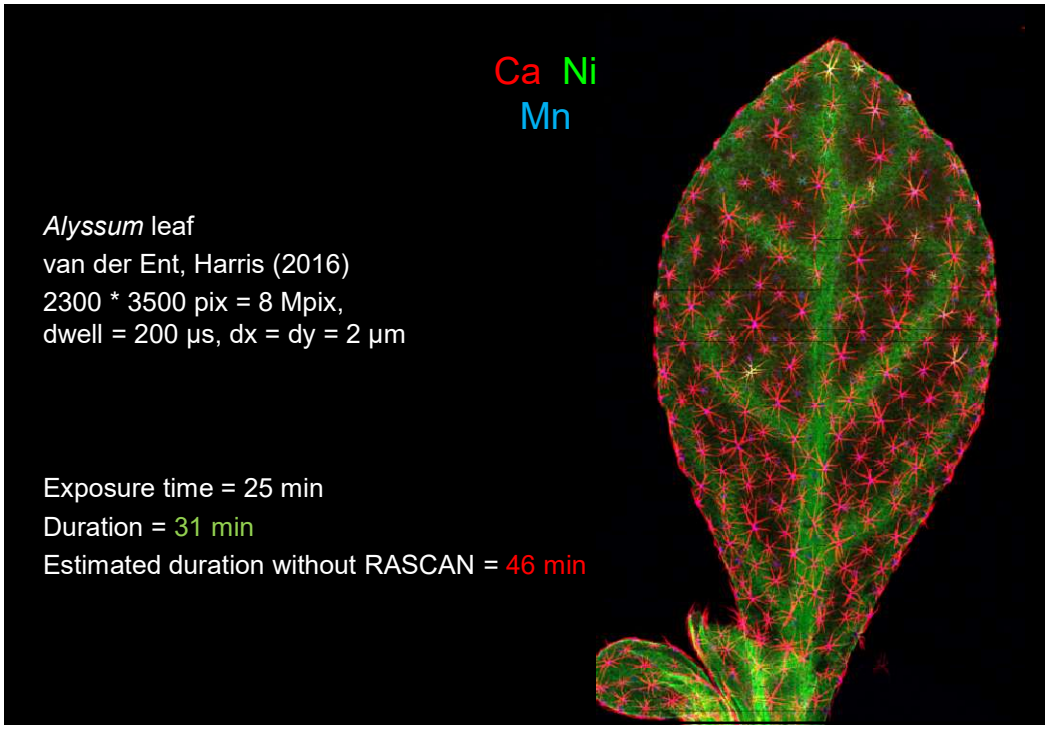

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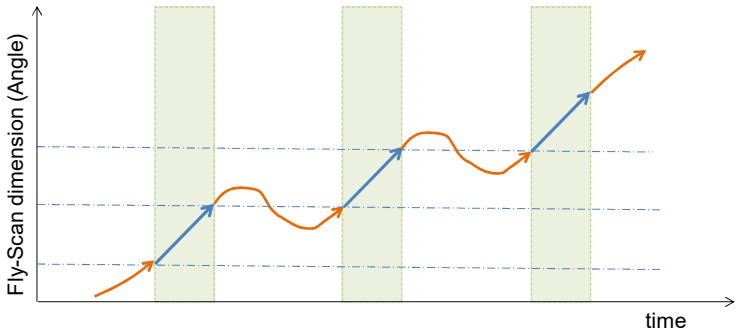
Application: Angular scan (MX)
1D skip-fly with shutter synchronisation

Shutter control: Open during fly-scan moves, closed during skip moves



Scan lines(points): scanned at REQUIRED position and velocity(dwell)

Skip moves: move back and attack the new scan line at the right timing

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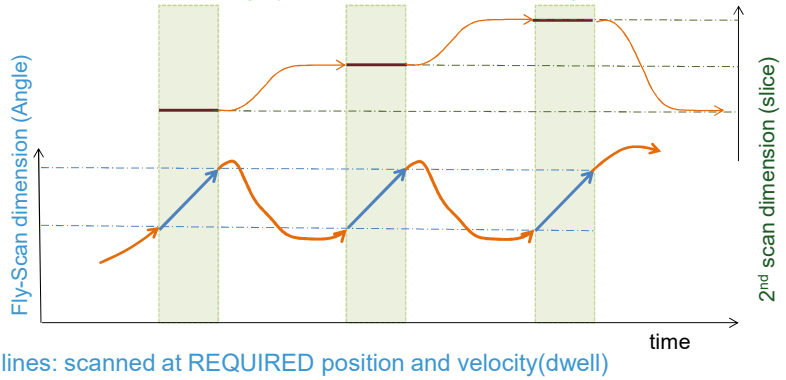
Application: CT scan (IMBL)
2D slicing

Shutter control: Open during fly-scan moves, closed during skip moves



Scan lines: scanned at REQUIRED position and velocity(dwell)

Skip moves: move back and attack the new scan line at the right timing

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Summary

- Separation of **"required"** and **"overhead"** components
- Effective mathematical formulation for Fly-scan optimisation problem
- Trajectory is optimized for tracking precision as well as speed
- Motion problem solved below user application level
- Implementation is robust and scalable
- Run-time control over Width, Pause/Resume, Shutter, etc.

- Asymmetric skip trajectories
- Adaptive estimation/correction of kinematic features limits

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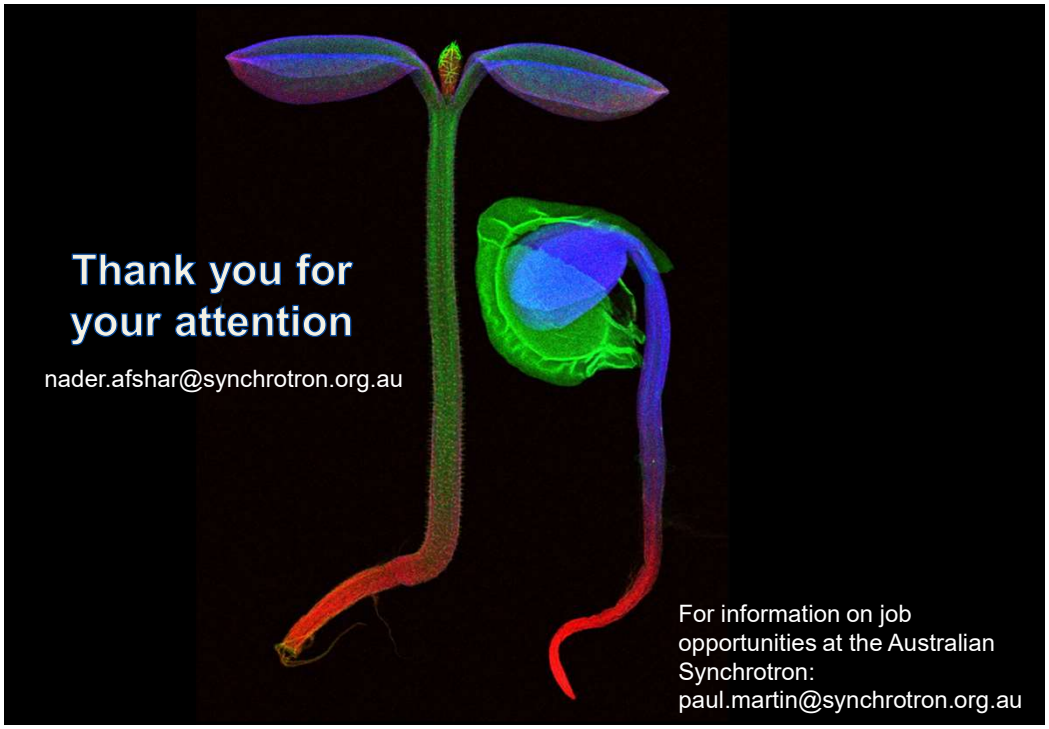
Thank you for your attention
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