Rebuilding a real Flight Simulator

An overview of 3 years work contributing to the Norwegian DC-10

Geert Rolf
Tehuis voor Bejaarde Computers,
Private museum for IT heritage,
Winssen, Nederland

This is all about...

- A real Flight Simulator:
  ## Link Miles
  ## DC-10 Level B Simulator

- Delivered to Continental Airlines in 1977.
  by Link-Miles Ltd, a division of SINGER Simulation Products in Lancing-Sussex, UK

- Donated for free to a group of Norwegian flightsimmers for serious hobby in 2004.

This Talk

- history of Return To Flight 2004 – 2011

  – what happened in 2004 – 2007?
  – an overview of our contribution to this project
    - rebuilding computer config (2008 / 2009)
    - replacing Night Vision System (2010 / 2011)

  – more details about the new Visual System: link between old stuff and MS Flight Simulator
    - printed article with more details available for you

  – two fragments of video for a good impression.

1977: installed at CoAir training facility (LA)

NSC
Nordic Simulator Center

DC-10 Return To Flight

What happened?
2004

- Continental Airlines offered the sim for free.

- Jan Fjeld formed group of people named **Nordic Simulator Center** and took the challenge.
- Cooperation with SVS school, aviation department: providing location.
- 12 tons of hardware shipped to Oslo.
- Trucked to Lillestrøm during the night escorted by police.

What happened?
2004 – 2011

- Rebuilding done by group of devoted people
  - Jacking up at level – 6DOF motion disabled
  - Recabling, reinstalling racks of equipment
  - Supply 110V power 50Hz; not 60Hz
  - Testing and Troubleshooting
  - Replacing two out of three computers
  - Intensive debugging: cables, modules.
- Returned to flight (fall 2009)
  - Night Vision System INOP.
  - Flying blind: IFR and Autopilot/Autoland
- Daylight Vision System (2010/2011)
  - Base development in 2010
  - Fine-tuning and adapting
  - Spin-off: new airports & navdata defined in old Sim.

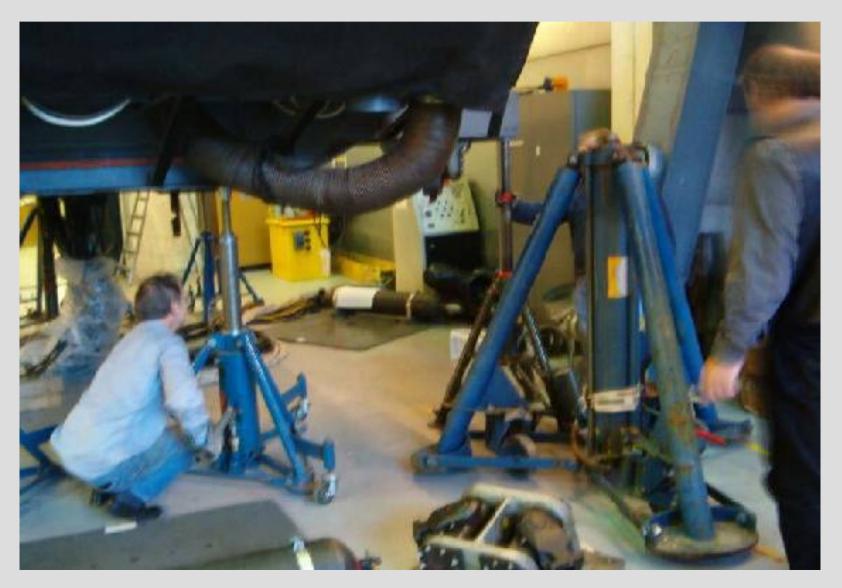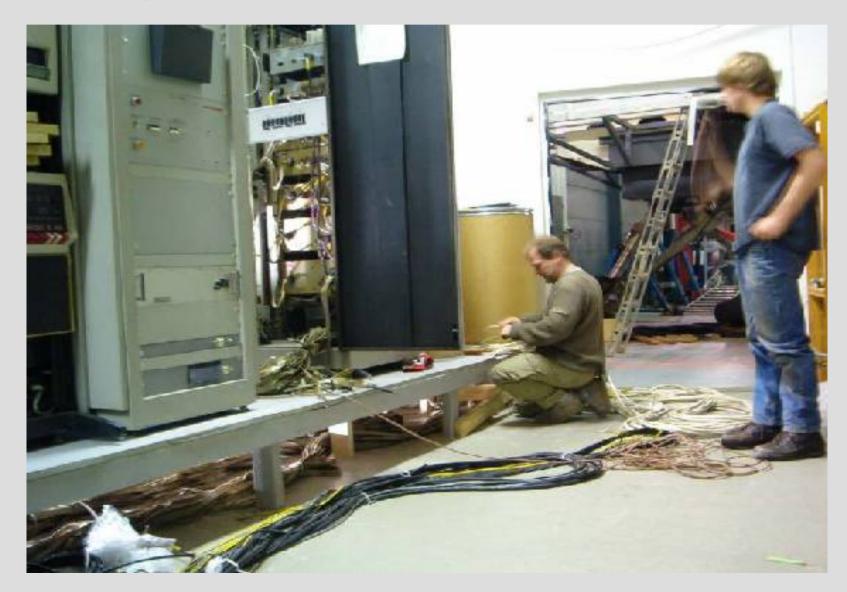# 2004: arrived at port of Oslo
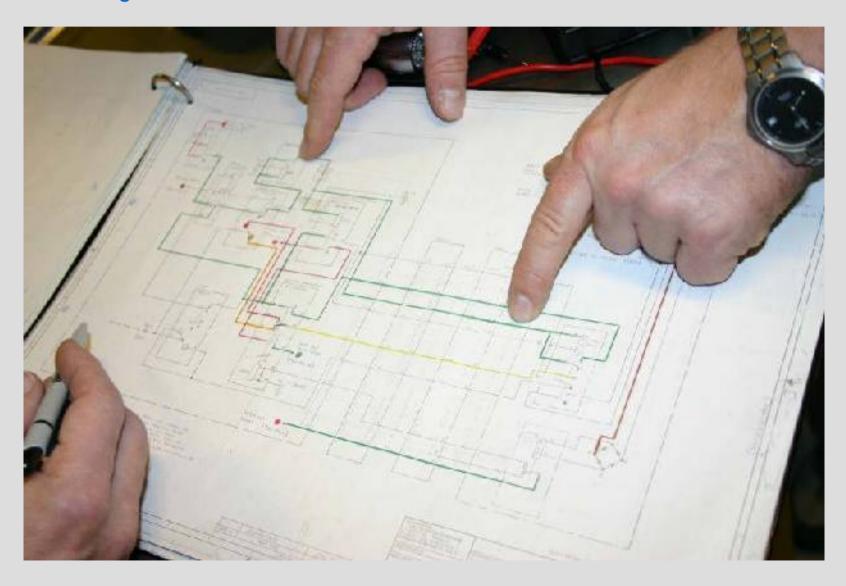
2004: hoisting

2004: does it fit?

2004: jacking up

2005/6: cabling...

2005/6: … by the book

Three old PDP-11s
show-stoppers!!

What happened?
2008 – 2009

- First contact december 2007: we have lot of |d|i|g|i|t|a|l| PDP-11 know-how.

- 1st visit january 2008:
  – Insufficient spare parts to get three "*oldies*" alive.
  – CPU-A extremely timing sensitive (cable length).
    - Expansion rack, two graphic units and a bus-repeater.

- Plan B
  – Replace CPU-A and -C by PDP 11/44: small box with large capacity PDP-11, easier to maintain.

CPU-A and CPU-B run the Sim
original config

- **32 Kbyte memory in CPU-B shared by CPU-A.**

- **CPU-A does the I/O with the Simulator**

- **CPU-B does most of the number crunching**

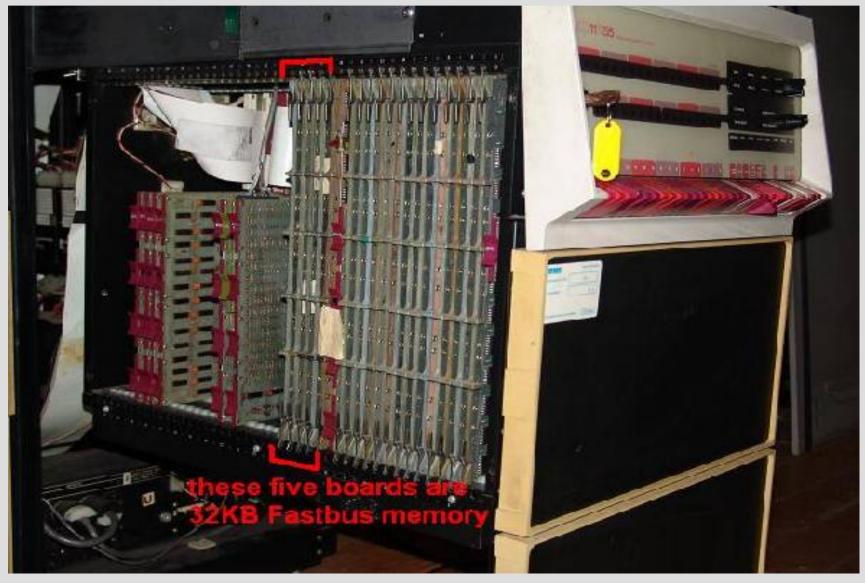| CPU-A	CPU-B
32 KB	32 KB
32 KB	32 KB
	32 KB
32 KB	32 KB
32 KB	32 KB
32 KB	32 KB
	32 KB
	24 KB

Plan B
replacing CPU-A by model 11/44

- Old style 18 bit bus is external side of UBI in "*new style*" CPU-A.

- I/O from "*Linkage*", done by HiSpeed Parrallel is kept local on the 18 bit bus by special setting of UBI.

- Required 15 changes in software: setting memory management hardware.

	11/44 Processor
22	8KB Cache
	Upto 4MB memory
	UBI
	HiSpeed Parrallel
18	Two VT30s & disk
	32KB Memory in CPU-B

these five boards are
32KB Fastbus memory

What is Linkage?

- A modular set of hardware to interface <u>everything</u> in the cockpit to a fast I/O interface.

  - One mastercontroller connected to CPU-A
  - Own bus with three subcontrollers
  - A large set of various types of interfaces:
    - Analogue in/out: low and high voltage
    - Digital in/out

- Config depends on cockpit/aircraft type
- I/O is done 20 times per second

Where does Linkage I/O end?

- ## In Shared Memory:
  - Digital IN
    288 bytes

  - Digital OUT
    320 bytes

  - Analogue IN
    288 bytes

  - Analogue OUT
    760 bytes
    - *total of 1656 bytes*

XTALK
(crosstalk)

Linkage I/O

What's in XTALK?

All global variables for all software modules.

- <u>Module "Engines" (EN)</u>: fuelflow triggered by throttles.
- <u>Module "Fuel" (SF)</u>: contents of tanks decreased by fuelflow. Outgoing data to fuel indicators.

XTALK
(crosstalk)

Fuelflow
Tank contents

Linkage I/O
Throttles
Fuel meters

- 2008
  - July: shipping "new" hardware.
  - October: installed and tested. FastBus memory taken home for testing and repair at chip level.
  - Still no signs of life at flight deck.
- 2009
  - April: circuit breaker test shows Linkage is alive: sequence of lights lit at flight deck.
  - June: ground loop diagnosed and repaired.
  - Fastbus Memory (two sets) installed:
    - one set is shared with CPU-A.
    - one more set to boost math routines used local.
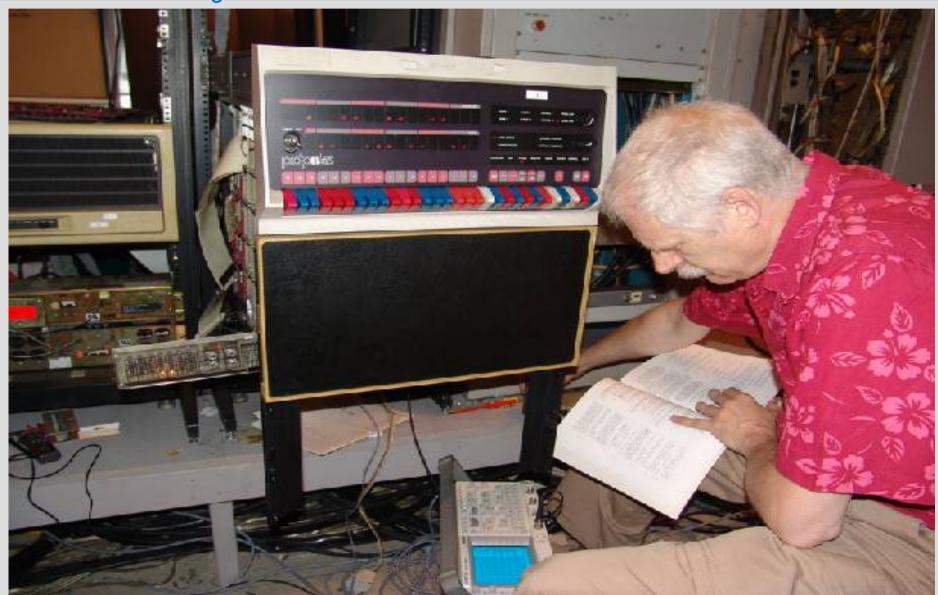   - at first: failed to get second set working.

Final preflight...

- Runs for 30 seconds: ends in "*CPU LATE*" error message.
  - Suspected CPU-A but discussion with former Link Miles employee pointed at CPU-B.
  - Did a software workaround for B being late.
    - Missing 2nd set FB mem (the Math booster) caused CPU-B being late: missing one cycle out of 20.

- *August 20: first "flight" of 35 minutes*.
    - Night Vision System: INOP
    - Flying blind on instruments!
- Getting stable later on by continued debugging.

Debugging PDP-11
diagnostic module and scope

Video fragment #1

- Shows site at SVS school, aviation department.

- Computer configuration: the two noisy boxes with white frontpanels are the "new" PDP-11/44s.

- APU startup at Flight Engineer panel
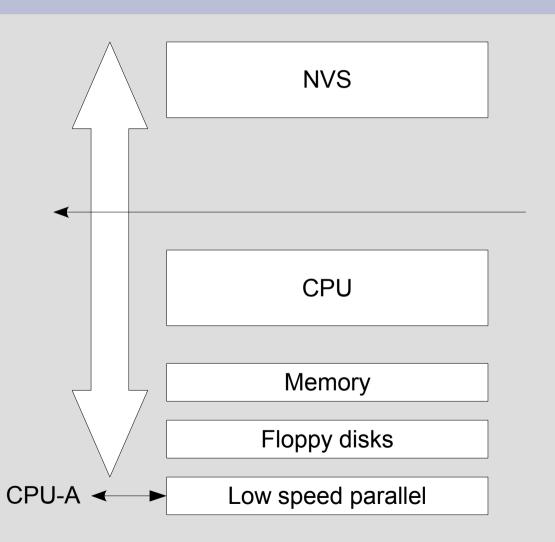
- Starting engine number 3

CPU-C: Night Vision System

- **CPU-C:**
  - Low speed parallel I/F connected with CPU-A
  - 64 byte messages received 20 times per second
  - NVS hardware considered hard to repair and calibrate

  - *NVS beyond repair...*

NVS

CPU

Memory

Floppy disks

CPU-A

Low speed parallel

Position Data
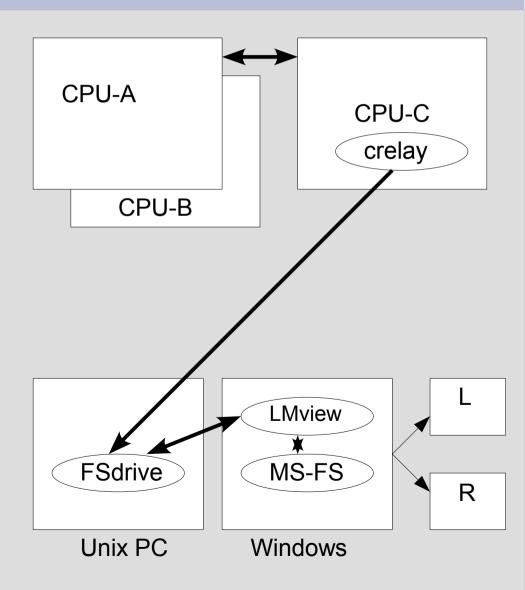## 64 bytes, 20x / second

- X and Y coordinates:
  - From runway threshold
  - 24 bits, $1/16^{th}$ foot = max 524288 feet
  - Range: -86Nm … +86Nm

- Z coordinate:
  - Feet AGL, silently converted to MSL at higher alt
  - 24 bits, $1/16^{th}$ foot

- Other data:
  - Speeds in X, Y, Z
  - Roll, pitch, yaw
  - Aircraft lights
  - Code of airport/runway
  - 16 bytes unused

DVS components

- Add network card to CPU-C.
- Crelay: collect data (64bytes) and send it to FSdrive.

- FSdrive: convert to data format for MS-FS:
  – X and Y from feet distance converted to world coordinates Lon/Lat
  – Z adjusted for groundlevel
  – Pitch, Roll, Yaw
  – Aircraft lights

- LMview: receive position info and set MS-FS position. (LUA language supported by FSUIPC)

Remote Development

- Cannot debug realtime applications over long distance (> 1000km).
  - Crelay developed by "simulating" CPU-A sending dummy test data over same hardware as in Norway. Testconfig: two PDPs in Winssen.

  - Flight data captured in Norway and replayed in Nederland for testing.
    - Houston circuit flown blindly early August 2010.
    - Able to replay three weeks later.
    - First experimental implementation a few days later.

Fine tuning

- ## X,Y conversion needs 64 bit precision, as Lon/Lat are significant in > 7th decimal.
  - ### needs tricky algorithms: spherical distance on earth globe, Haversine algorithms.

- ## DC-10 has Inertial Navigation System:
  - ### *can fly all over the world beyond visual limit*.
  - ### No navdata required as for modern FMS.
- ## Extending limits in X and Y axis by counting the overflows:
  - ### add 86NM on first wrap-around,
  - ### another 172 NM at second wrap around.

New Airports & testflight

- Spin-off project: add new airports to old Sim
  - Webbased tools use Google Maps for preview
  - Close match between Google Maps and MS-FS
  - First to add: *Oslo lufthavn Gardermoen!*

- Testflight Paris CdG – Oslo Gardermoen
  - January 2011
  - Error in Longitude: INS read-outs pointed at real position: ±100 KM west of visual.
  - "talked" into right direction: visual switched to Oslo at ± 45 NM distance. Landed runway 01R...

XY extension: plan B

- Modified original sim to add aircraft Lon/Lat to position data.
  - FSdrive in "B" mode uses aircraft Lon/Lat.
  - However, landing in "B" mode at Bergen "Flesland" showed offset between visual and instruments.

- **Landings should use X and Y coordinates, not Lon/Lat!**
  - switch from "A" to "B" mode climbing through 2000 ft AGL
  - back to "A" mode descending through FL100, or 4000 or below 2000 ft.
  - smoothing out differences in position.

- Paris to Oslo now < 1 KM difference.

Video fragment #2

- Take off KLAX runway 24R

- Daylight landing runway 24R

- Night landing runway 24R

Pointers

- www.bejaardecomputers.nl
  - Geert.Rolf@xs4all.nl

- www.dc10.no

- www.link-miles.co.uk

- http://www.visitnorway.nl/

Hope you enjoyed

- Questions?

- Vragen?

- Spørsmål?