

# Advanced flexible automation cell control for aerospace manufacturing

66044 Flexible Automation  
A research paper evaluation

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# Outline

Challenges in Automation in Aerospace Industry

Flexible Manufacturing System

FLEXA Project

FLEXA Cell Architecture Design

FLEXA Control Architecture

FLEXA Cell Coordinator

FLEXA Database and Recipe Generation

FLEXA Cell Coordinator Scheduler

FLEXA Planner Graphical User Interface

Testing phase

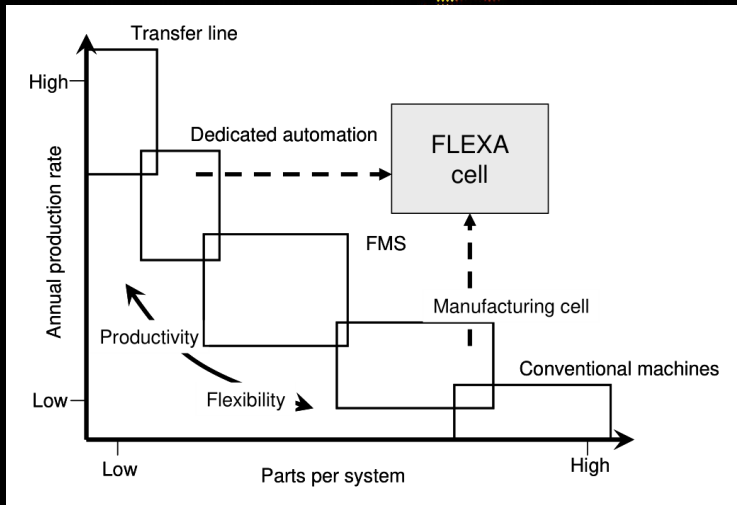
Conclusions

# Challenges in Automation in Aerospace Industry

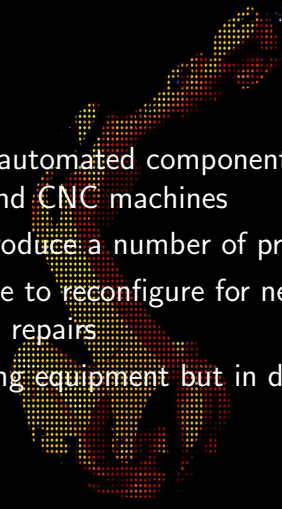
- ▶ Job shop production specification
  - ▶ Very little use of automation in aerospace manufacturing
  - ▶ Relatively small product volumes
- ▶ Very high standard of quality
- ▶ Constant improvement of production
- ▶ Repair of components

# Flexible Manufacturing System

Manufacturing today



# Flexible Manufacturing System

- 
- ▶ Integration of automated component storage, tool delivery and CNC machines
  - ▶ Designed to produce a number of predefined products
  - ▶ Significant time to reconfigure for new parts, troublesome in repairs
  - ▶ Same processing equipment but in different locations

# Flexible Manufacturing System

## FMS Architecture

- ▶ Consists of two or more computer-managed workstations, material transport system and another computer that controls transportation
- ▶ Optimization of flexible systems
  1. Holonic Manufacturing
  2. Evolvable Assembly System (EAS)
  3. Instantly Deployable Evolvable Assembly System (IDEAS)
- ▶ Software Features
  1. Application of Service-Oriented Architectures (SOA)
  2. Connectivity using web service interfaces
  3. Capture of requirements from graphical information
  4. Capture parameters such as safety and security
  5. Limitations

# FLEXA Project

- 
- ▶ An innovative approach to cell control and organisation
  - ▶ Data management and control architecture
  - ▶ Classes of manufacturing attributes considered in design
    1. Cost
    2. Quality
    3. Time
    4. Flexibility

# FLEXA Cell Architecture Design

- 
- ▶ Support total flexibility within a semi-chaotic manufacturing environment
  - ▶ Conventional control methodology impractical
  - ▶ Flexible and sophisticated data management system
  - ▶ Adaptive to accommodate shape changes and deformation



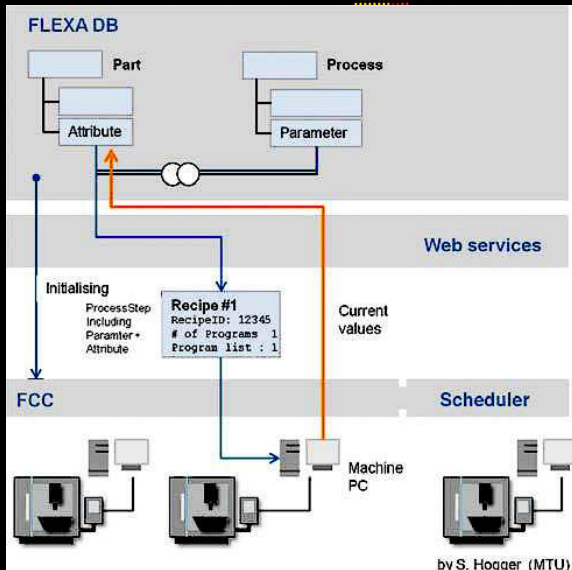
# FLEXA Control Architecture

## FCA Elements

- ▶ The FLEXA Database (FDB)
- ▶ The FLEXA Cell Coordinator (FCC)
- ▶ Application Top Level Software
- ▶ Recipe: Link between FDB and FCC

# FLEXA Control Architecture

## FCA Structure



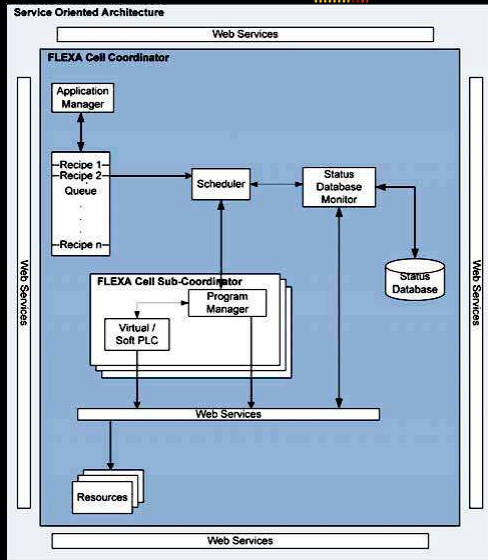
# FLEXA Cell Coordinator

## Attributes

- ▶ Uses Software PLCs on the cell level without dedicated hardware, but above individual physical PLCs
- ▶ All subsystems are classified as networked resources with a common interface, thus automatically identifiable
- ▶ Generating recipes after identification of production sequence, which allow to identify and allocate required resources and load programming information
- ▶ Has overall control and allocates virtual sub-coordinators for each cell for duration of the task
- ▶ Unloads virtual cell sub-coordinators after task completion, frees up used resources
- ▶ Stores its own database for status information in case of recovery from a failure state


# FLEXA Cell Coordinator

## FCC Structure



# FLEXA Cell Coordinator

Individual elements

- ▶ Application Manager
  - ▶ FLEXA Scheduler
  - ▶ Status Database and Monitor
  - ▶ Recipe Queue
  - ▶ Cell Sub-coordinator
- 

# FLEXA Database and Recipe Generation

## Requirements

An additional software is necessary in order to use the Control Architecture



# FLEXA Database and Recipe Generation

## Requirements

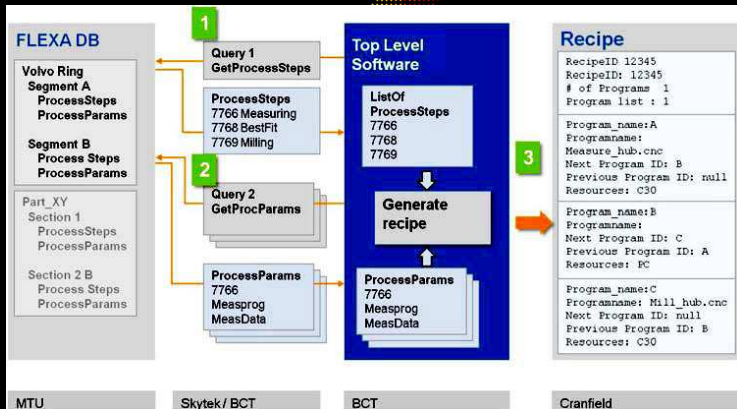
An additional software is necessary in order to use the Control Architecture

Application Top Level Software



# FLEXA Database and Recipe Generation

## FDB Diagram





# FLEXA Database and Recipe Generation

## Control Architecture

### Steps:

1. Identification of the list of processes
2. Extraction from part structure of all process defining parameters with corresponding values
3. Generation of recipe



# FLEXA Database and Recipe Generation

After recipe extraction

## FCC - Scheduler & Application Manager

- ▶ uploads the recipe and schedules it accordingly
- ▶ creates and activates a sub-coordinator
- ▶ stores the results of task from PM in own database and sends relevant results to FLEXA Database

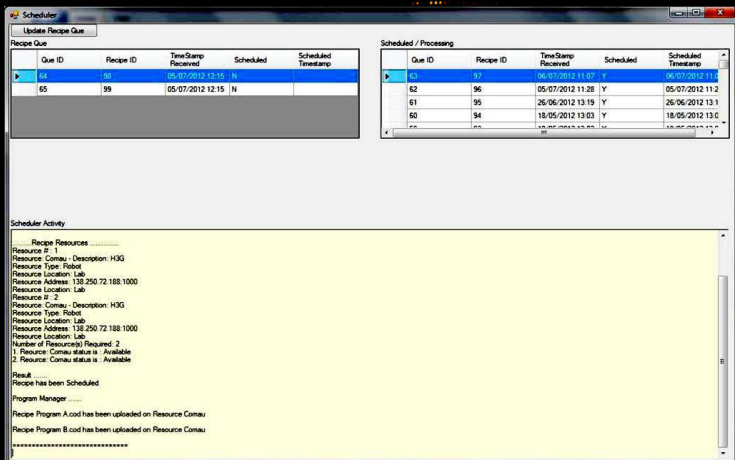
## Programme Manager - Cell Sub-coordinator

- ▶ receives the recipe
- ▶ downloads the relevant programme onto allocated resources
- ▶ sends back relevant data and results to FCC Application Manager after task completion

## Software PLC

- ▶ starts the process and acts on the outside like a conventional hardware PLC
- ▶ uses networked digital inputs and outputs

# FLEXA Cell Coordinator Scheduler



The screenshot shows the FLEXA Cell Coordinator Scheduler interface. It features a title bar with standard window controls. Below the title bar is a menu bar with 'Update Recipe Queue'. The main area is divided into three sections: 'Recipe Queue', 'Scheduled / Processing', and 'Scheduler Activity'.

**Update Recipe Queue**

**Recipe Queue**

Queue ID	Recipe ID	Time Stamp Received	Scheduled	Scheduled Timestamp
64	98	05/07/2012 12:15	N	
65	99	05/07/2012 12:15	N	

**Scheduled / Processing**

Queue ID	Recipe ID	Time Stamp Received	Scheduled	Scheduled Timestamp
63	97	05/07/2012 11:07	Y	05/07/2012 11:07
62	96	05/07/2012 11:28	Y	05/07/2012 11:28
61	95	25/06/2012 13:19	Y	25/06/2012 13:19
60	94	18/05/2012 13:03	Y	18/05/2012 13:03

**Scheduler Activity**

Recipe Resources .....

Resource # 1

Resource: Comau - Description: H3G

Resource Type: Robot

Resource Location: Lab

Resource Address: 138.250.72.188:1000

Resource Location: Lab

Resource # 2

Resource: Comau - Description: H3G

Resource Type: Robot

Resource Location: Lab

Resource Address: 138.250.72.188:1000

Resource Location: Lab

Number of Resource(s) Required: 2

1. Resource: Comau status is: Available

2. Resource: Comau status is: Available

Result .....

Recipe has been Scheduled

Program Manager .....

Recipe Program A.cod has been uploaded on Resource Comau

Recipe Program B.cod has been uploaded on Resource Comau

\*\*\*\*\*

# FLEXA Planner Graphical User Interface

The screenshot displays the FLEXA Planner Graphical User Interface (GUI) with various components and annotations:

- Annotations:**
  - 1: Product structure
  - 2: Process modules
  - 3: Overview
  - 4: Attributes
  - 5: Repair cases
  - 6: Repair
  - 7: Processes
  - 8: Part classes
  - 9: Processes
  - 10: Generic job description
  - 11: Condition
  - 12: Parameter - attribute - link
- Navigation Bar:**
  - Arbeitsplätze
  - Betriebsmittel
  - Typen
  - Produktstruktur
  - Prozessmodule
  - Logout
- Navigation Panel:**
  - Übersicht
  - Merkmale
  - Schadensfälle
  - SF-Matrix
  - Prozesse
- Part Classes (Left Panel):**
  - Gehäuse
    - Allgemeine Bauteilbereiche
      - Gehäusemantel AUSSEN
      - Gehäusemantel INNEN
      - Streben
    - parts
      - Bauteilbereiche
        - Gehäusemantel AUSSEN
        - Gehäusemantel INNEN
        - Streben
  - Labyrinthdichtung
    - Allgemeine Bauteilbereiche
      - Bauteile
  - Leitkranz
    - Allgemeine Bauteilbereiche
      - Bauteile
  - Leitung / Rohr / Abgasleitung
  - Ring
    - Allgemeine Bauteilbereiche
      - Bauteile
  - Schaukel
  - Test
  - Träger
  - Welle
- Processes (Center Panel):**

Bauteilspezifische Prozesse für Bauteil [RB 199 ZWG Aussen].  
Erstellung und Verwaltung von bauteilspezifischen Prozessen.

  - Bohren Lochkreis: CB
  - Drehen
  - Eindringprüfen nach Riss-Schweißen
  - Eindringprüfen vor Schweißen
  - Fräsen der Strebenkanten
  - Maßprüfung
  - Röntgenprüfen nach Kanten-Schweißen
  - Röntgenprüfen vor Schweißen
  - Schweißen der Risse
  - Schweißen der Strebenkanten
  - Vorbereiten der Risse
  - Wärmebehandlung nach Schweißen
- Generic Job Description (Right Panel):**

1. Vorrichtung nach Skizze aufbauen und ausrichten.  
2. Bauteil erzeugen und ausrichten nach Skizze.  
die Basis der Bearbeit...

Eigene Beschreibung
- Condition (Right Panel):**

toleranzüberschreitungen > 0
- Parameter - attribute - link (Right Panel):**

Name	Beschreibung	Merkmal	Wert	Typ	Verpflicht.	Richtung	ID
Skizze	Vorricht...	---	---	Skizze	Nein	IN	1032
Messse...	verwen...	Messse...	---	Länge	Nein	IN	1038
Stirnse...	Hilfsmitt...	Stirnse...	31-832...	Bohrer	Nein	IN	1035
Vorricht...	Spann...	Vorricht...	28F436...	Bohr-Vo...	Nein	IN	903
Stirnse...	Hilfsmitt...	Stirnse...	31-823...	Bohrer	Nein	IN	1036
NC-Pro...	Bohrpro...	NC-Pro...	28L432...	CNC-Pr...	Nein	IN	1033
Absolut...	Analog...	Absolut...	&1953...	String	Nein	IN	1037

# Testing phase

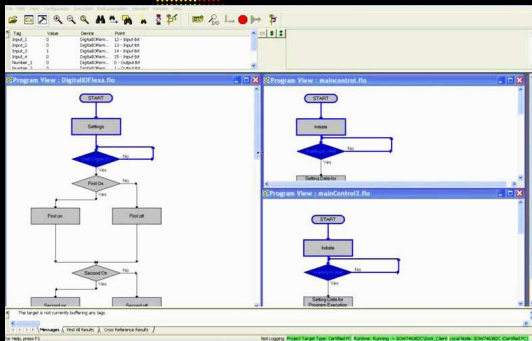
## Participants

- ▶ Germany - Motoren- und Turbinen-Union Aero Engines GmbH
- ▶ Germany - BCT Steuerungs- und DV-Systeme GmbH
- ▶ United Kingdom - Cranfield University Aero-Structure and Assembly Lab
- ▶ Ireland - Skytek



# Testing phase

## FLEXA Cell Coordinator Test Cells



# Testing phase

Testing scenarios

## ► Scenarios

1. Real Test
2. Simulation
3. Real and simulation test



# Testing phase

## Full FLEXA System Test

### ► Scenario 1

1. Purpose: control of all cells at the same time capability test of the FCC
2. 3 cell coordinators
3. 3 resources



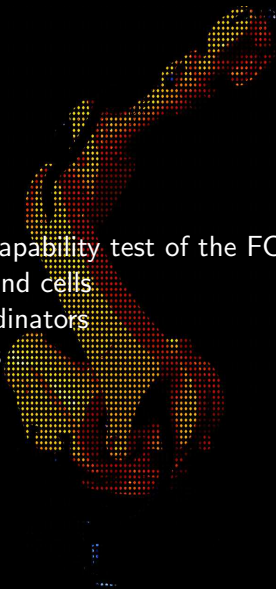


# Testing phase

## Full FLEXA System Test

### ► Scenario 2

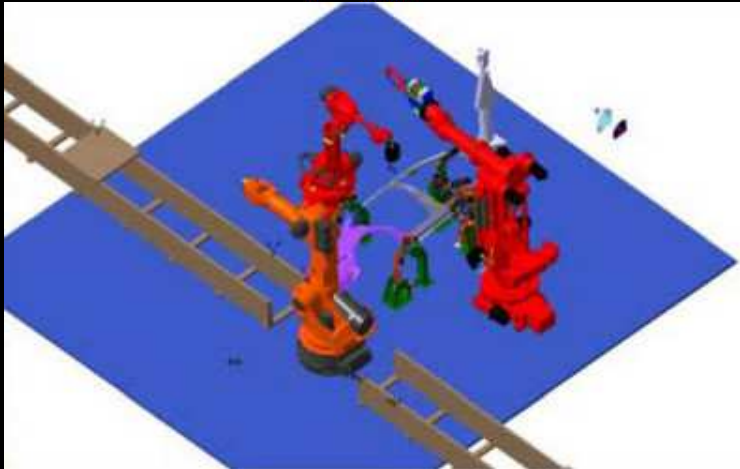
1. Purpose: capability test of the FCC with multiple resources and cells
2. 2 cell coordinators
3. 4 resources



# Testing phase

## Full FLEXA System Test

### ► Scenario 2



# Testing phase

## Full FLEXA System Test

### ► Scenario 3

1. Build upon scenario 2
2. Purpose: capability test of the FCC across multiple cells in multiple locations
3. 3 cell coordinators
4. 4 resources



# Testing phase

## Results

- ▶ FLEXA Cell Coordinator test cell
- ▶ Scenario 1
- ▶ Scenario 2
- ▶ Scenario 3



# Criticism

- ▶ TCP/IP capable hardware requirement is a restriction on using possible tools
- ▶ TCP/IP approach has all of the problems that come with using Ethernet/WLAN
- ▶ Distributed system control
- ▶ Web services
- ▶ Latencies and delays
- ▶ Safety issues
- ▶ Persistence and integrity issues of database
- ▶ An ever expanding approach
- ▶ Too few specifics

# Possible improvements and further steps

- ▶ Introduction of standards and norms
- ▶ Self optimizing premise of the FLEXA system and individual components
- ▶ Compatibility with other solutions like ASI, xDNC
- ▶ Improve User Interface
- ▶ Introduce Augmented Reality as an interactive tool for cell control

