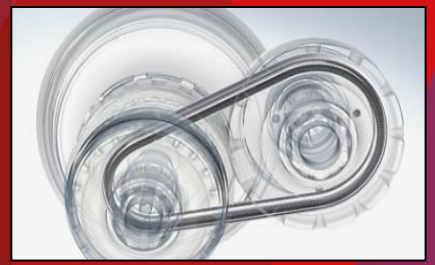
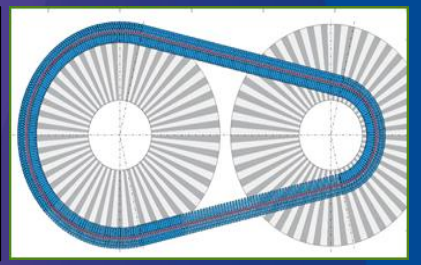




Dirk Twisk

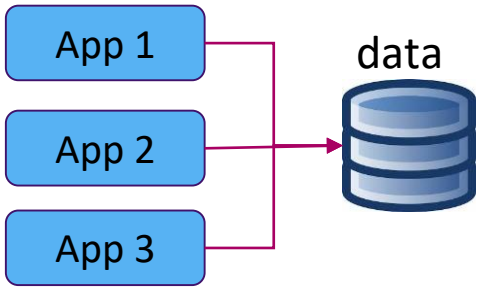
Bosch Transmission Technology

Using Matlab production server for product lifetime calculations

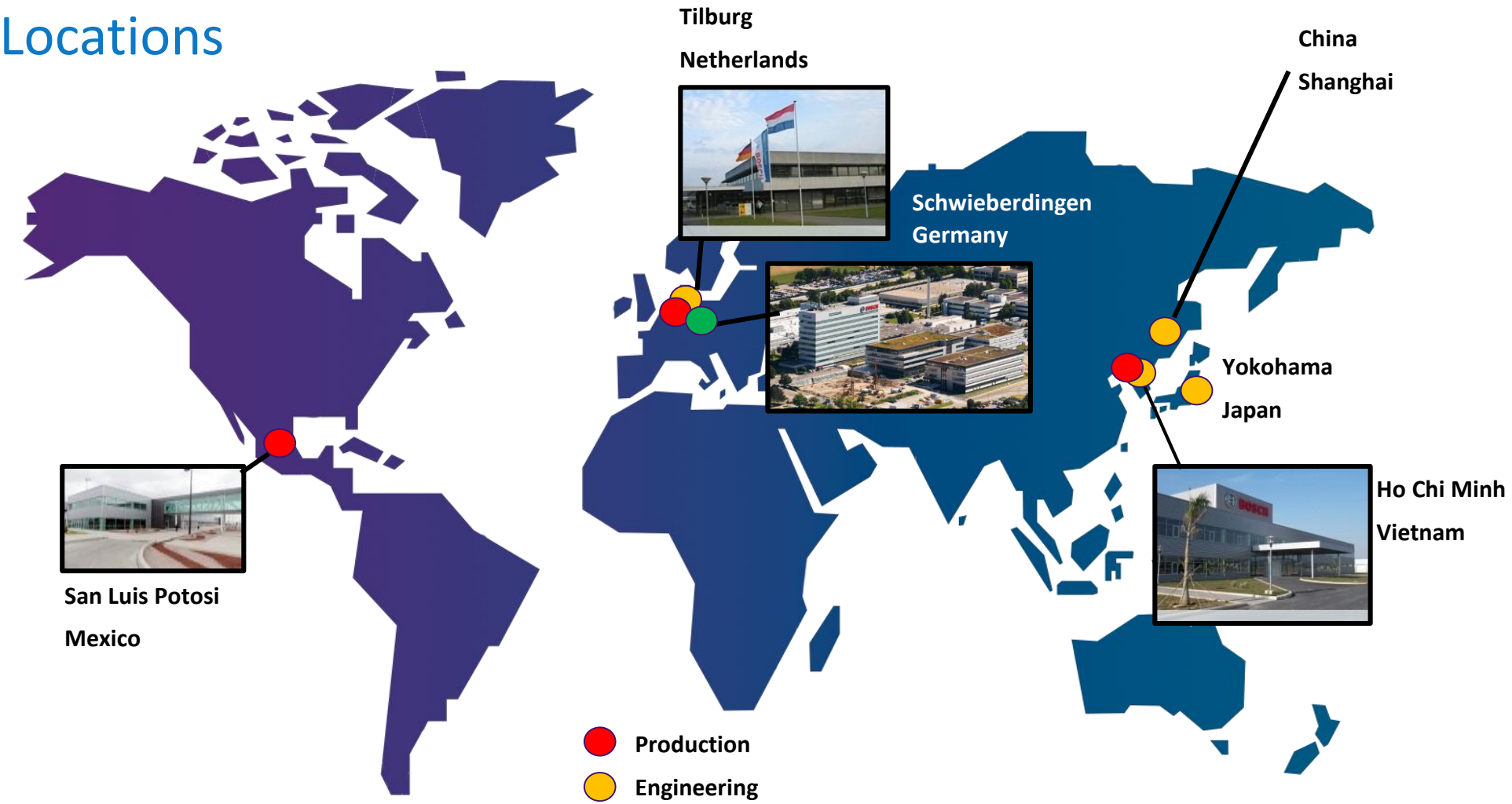
Contents

Engineering calculations at Bosch Transmission Technology BTT

- All engineers should use the same tools.
  - Many tools are developed in house – what is the latest version?
- Quality procedures are used to develop and verify software tools.
  - Use versioning systems and (unit) tests.
- Everybody uses the same data
  - Multiple channels of communication internally and externally.
- Data can be shared between applications.
- Effective use of computational resources.



BTT Locations



BOSCH

Introduction to the CVT

Model calculations for Push Belts

- Designs are made by engineers, based on user requirements:
  - Maximum torque and power, expected lifetime (kms), ratio coverage, package size.

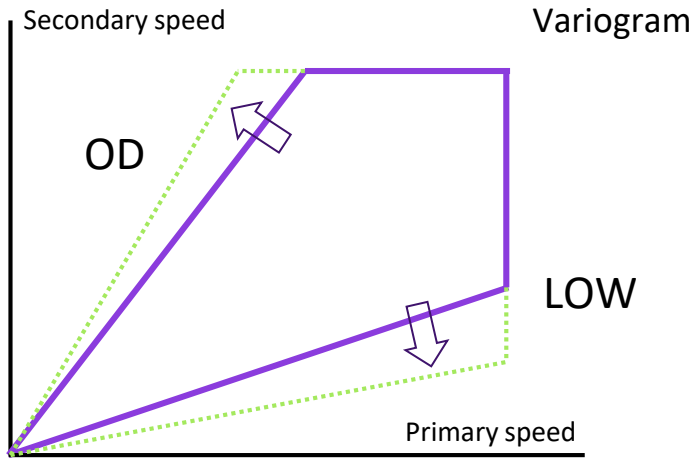
- Detailed calculation results are shared with the customer.
  - Bosch designs and produces the push-belt only.
  - All other transmissions components are made by the customer.
  - Integration engineering.

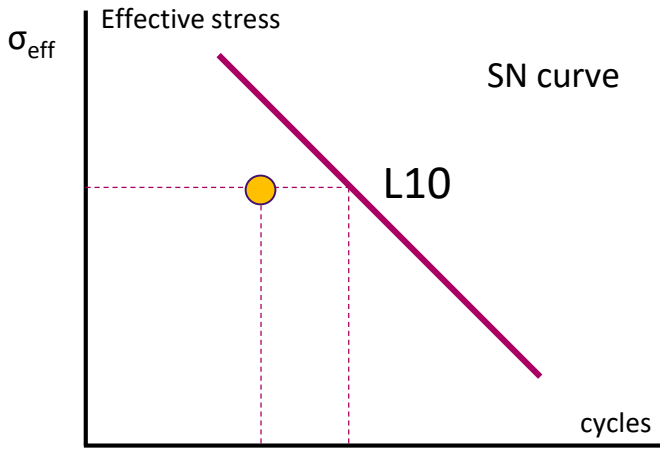
- Calculations are made during all stages of the development process.
  - Initial offering to customer
  - Product Development.
  - Verification in Laboratory.

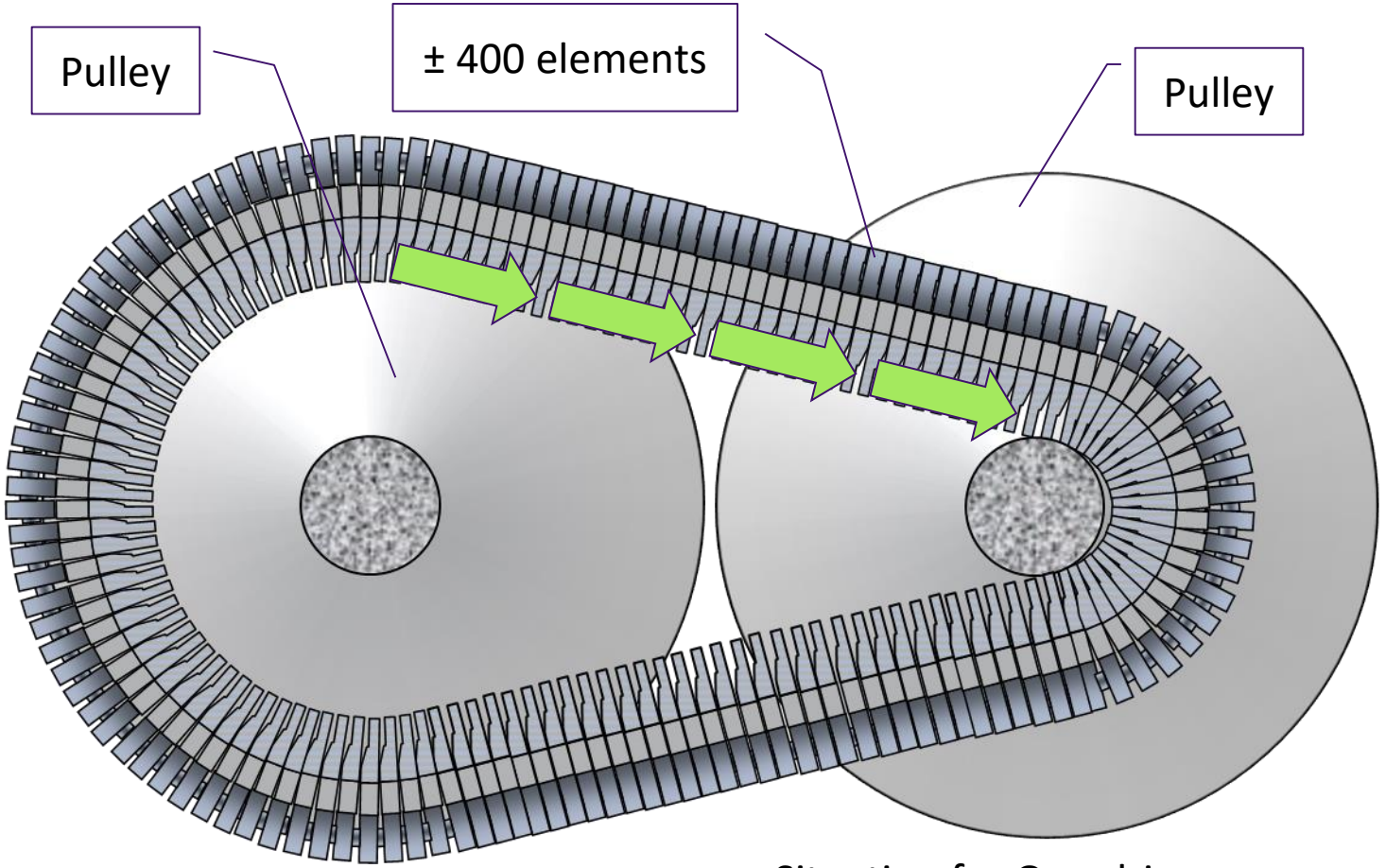
Engineering calculations

- Geometrical calculations
  - Achieve a large Ratio Coverage.
    - Deep LOW is for take-off performance
    - OD is required for fuel efficiency
  - Determine build size. Smaller and less weight is better.

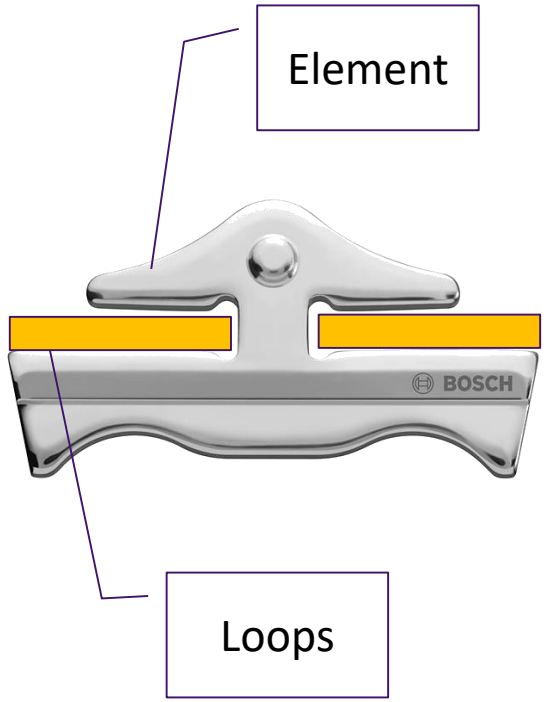
- Forces and Stresses
  - Calculate forces and stresses acting on the system.
  - Calculate expected lifetime of the push belt
    - Number of stress cycles before most critical part fails.



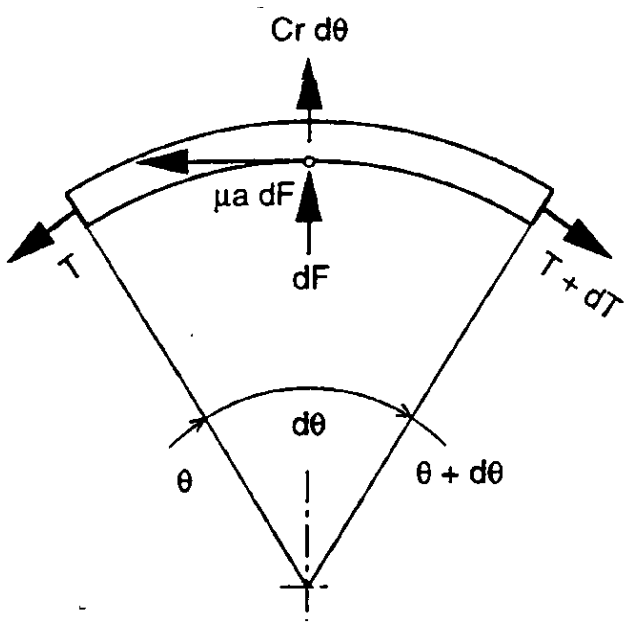




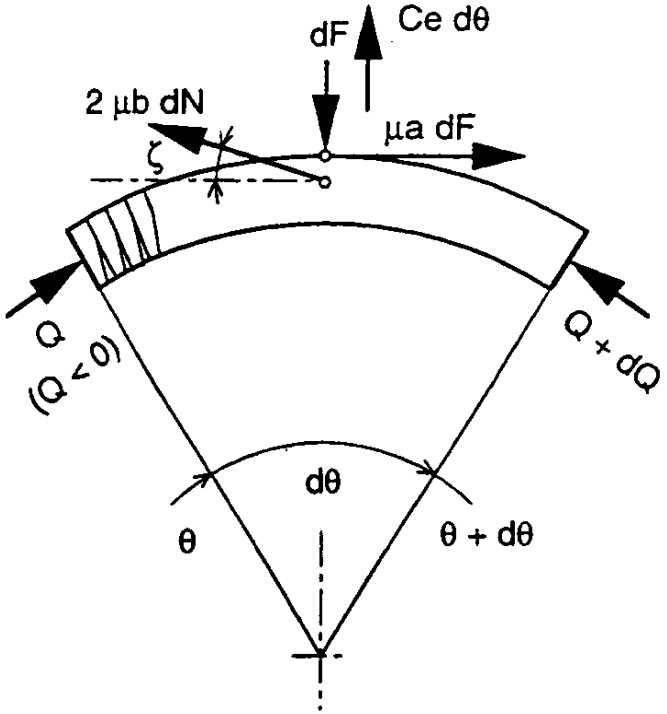
Situation for Overdrive



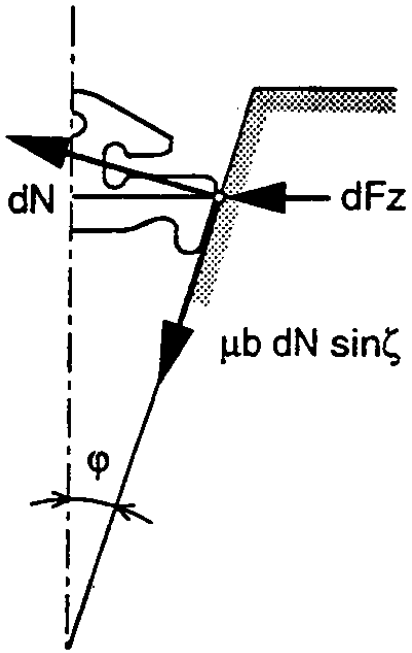
Force balance model



Loop set part



Element string part



Pulley sheave part

Solving the problem in Matlab

Call to fsolve
Target function
Differential equations

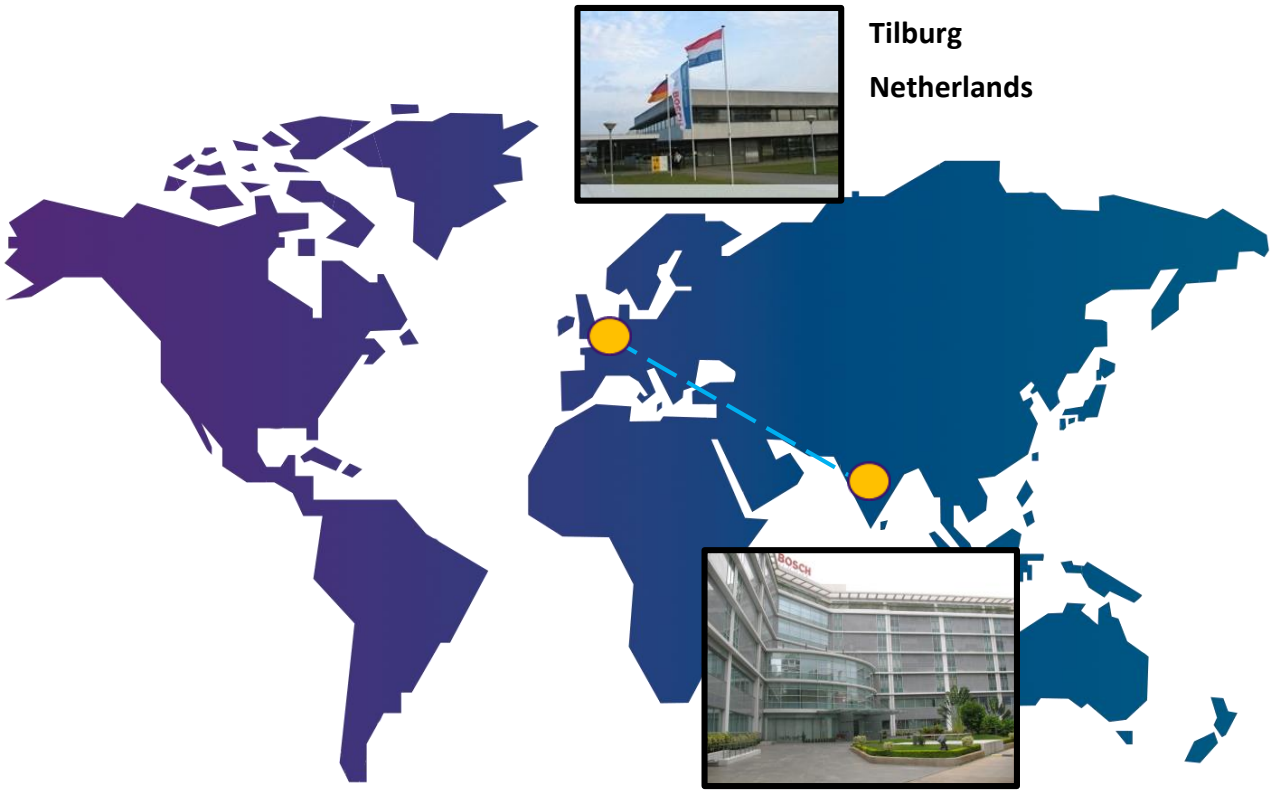
```
[R1,R2,exitflag] = fsolve(@(SolvVec) FuncName(SolvVec,ConstVec),InitVec,options);
```

```
% ------------------------------------------------------------------------
  function [F] = Calc_Solution_Above_Transition(x,y)
     fdmax  = x(1);
     fstrek   = x(2);
     beta_s = x(3);
     faxs     = y(1);

     F = [Fdsec(alphas,fdmax,fstrek,beta_s)
          FaxsA(fdmax,fstrek,beta_s)+FaxsB(fdmax,fstrek,beta_s)-faxs
          Msecf(fdmax,fstrek)-Ms];
  end
  % ------------------------------------------------------------------------

  function [F] = Calc_Solution_Below_Transition(x,y)
     fdmax  = x(1);
     fstrek   = x(2);
     beta_s = x(3);
     faxs     = y(1);

     F = [Fdsec(alphas,0.0,fstrek,beta_s)-fdmax
          FaxsA(0.0,fstrek,beta_s)+FaxsB(0.0,fstrek,beta_s)-faxs
          Msecf(-fdmax,fstrek)-Ms];
  end
```

```
%------------------------------------------------------------------------
  function [F] = Fdsec(phi,fdmax,fstrek,b_s)
  if (model == BOVEN)
       F = (fdmax+Csch-(fstrek-Csn)*exp(-mu_lr*(alphas-b_s)))*exp(con10b*(phi-(alphas-b_s)))+(fstrek-Csn)*exp(-mu_lr*phi)-Csch;
     else
       F = (         Csch-(fstrek-Csn)*exp(-mu_lr*(alphas-b_s)))*exp(con10b*(phi-(alphas-b_s)))+(fstrek-Csn)*exp(-mu_lr*phi)-Csch;
     end
  end
```

```
%------------------------------------------------------------------------
  function [F] = FaxsA(fdmax,fstrek,b_s)
  if alphas-b_s < COMPZERO
       F = 0.0;
     else
       scale = 10000;
       F     = scale*quadl(@(phi) dFaxsA(phi,fdmax,fstrek,scale),0.0,(alphas-b_s));
     end
  end

  %------------------------------------------------------------------------
  function [F] = FaxsB(fdmax,fstrek,b_s)
    con20 = 0.5*(1-tan(lambda_sec)*mu_lf*sin(gammalfb))./(tan(lambda_sec)+mu_lf*sin(gammalfb));
    if model == BOVEN
       F = con20*((-1/con10b)*(fdmax+Csch-(fstrek-Csn)*exp(-mu_lr*(alphas-b_s))))*(exp(con10b*b_s)-1);
    else
       F = con20*((-1/con10b)*(     Csch-(fstrek-Csn)*exp(-mu_lr*(alphas-b_s))))*(exp(con10b*b_s)-1);
    end
  end
```

How to Implement

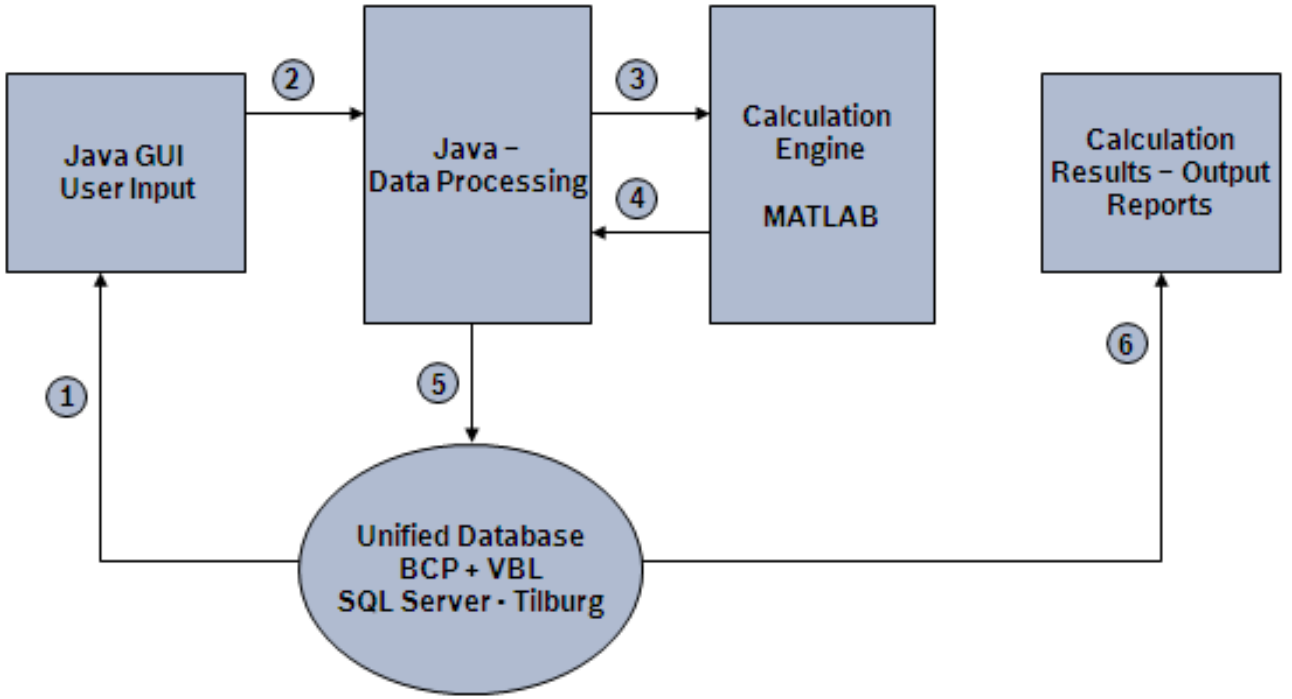


BTT - Tilburg
Mechanical Engineering
Transmission Design (CVT)
Modelling
Matlab

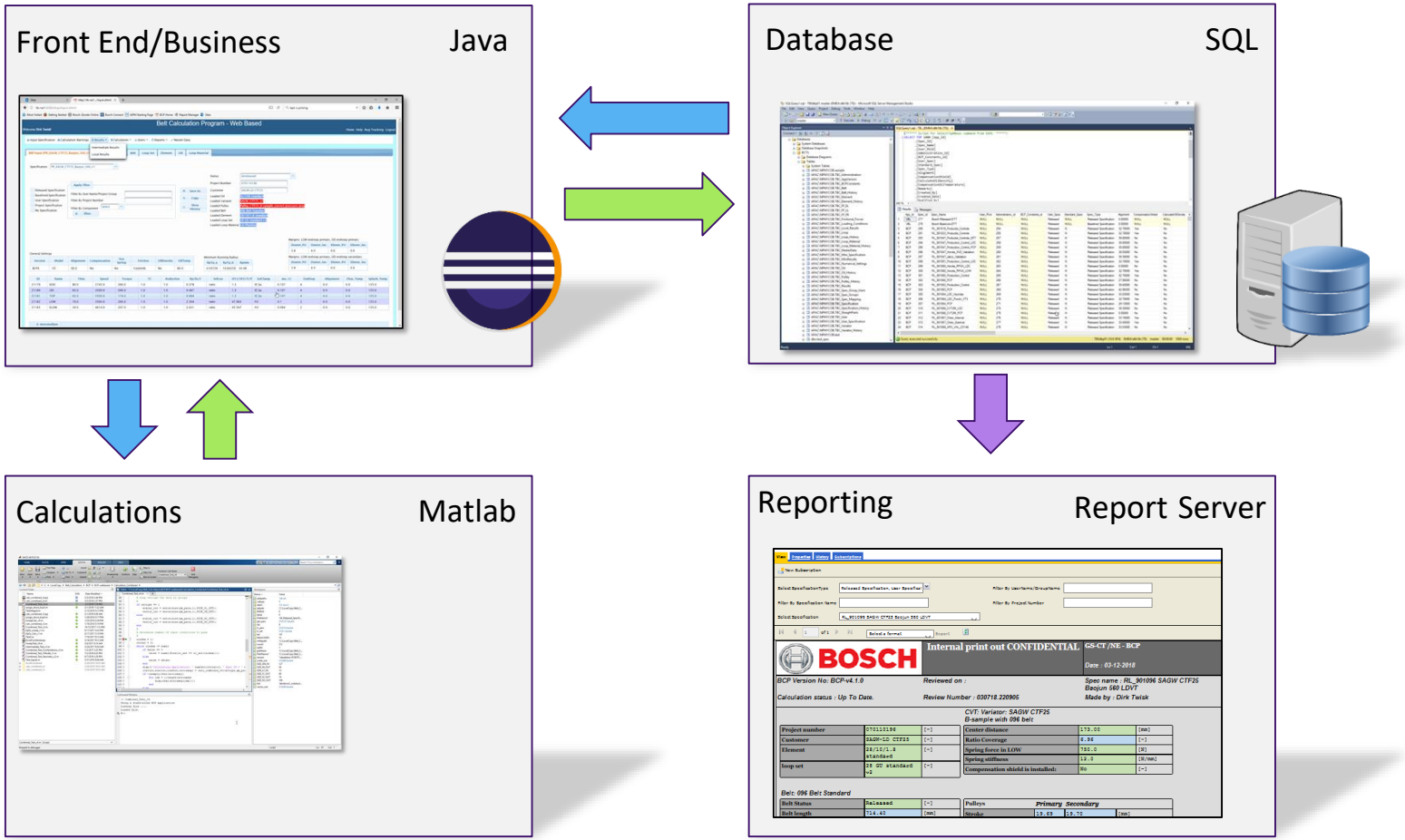
RBEI - Bangalore
Software Systems Design
Databases
Java
Matlab

System Design

- Server stores inputs and outputs for several applications
- Start with complete variator models: BCP and VBL
- Data can be accessed by all users (engineers)
- Different interfaces and business logic for different applications.



System Implementation



Development – traditional design

PS-CT/EAC

Product Development

Model Development

1. Write Code
2. Test Code
3. Compile Code
4. Jar File(s)

RBEI/ETC

Software Development

Information Systems

1. Write Code
2. Test Code
3. Compile Code
4. Create Executable

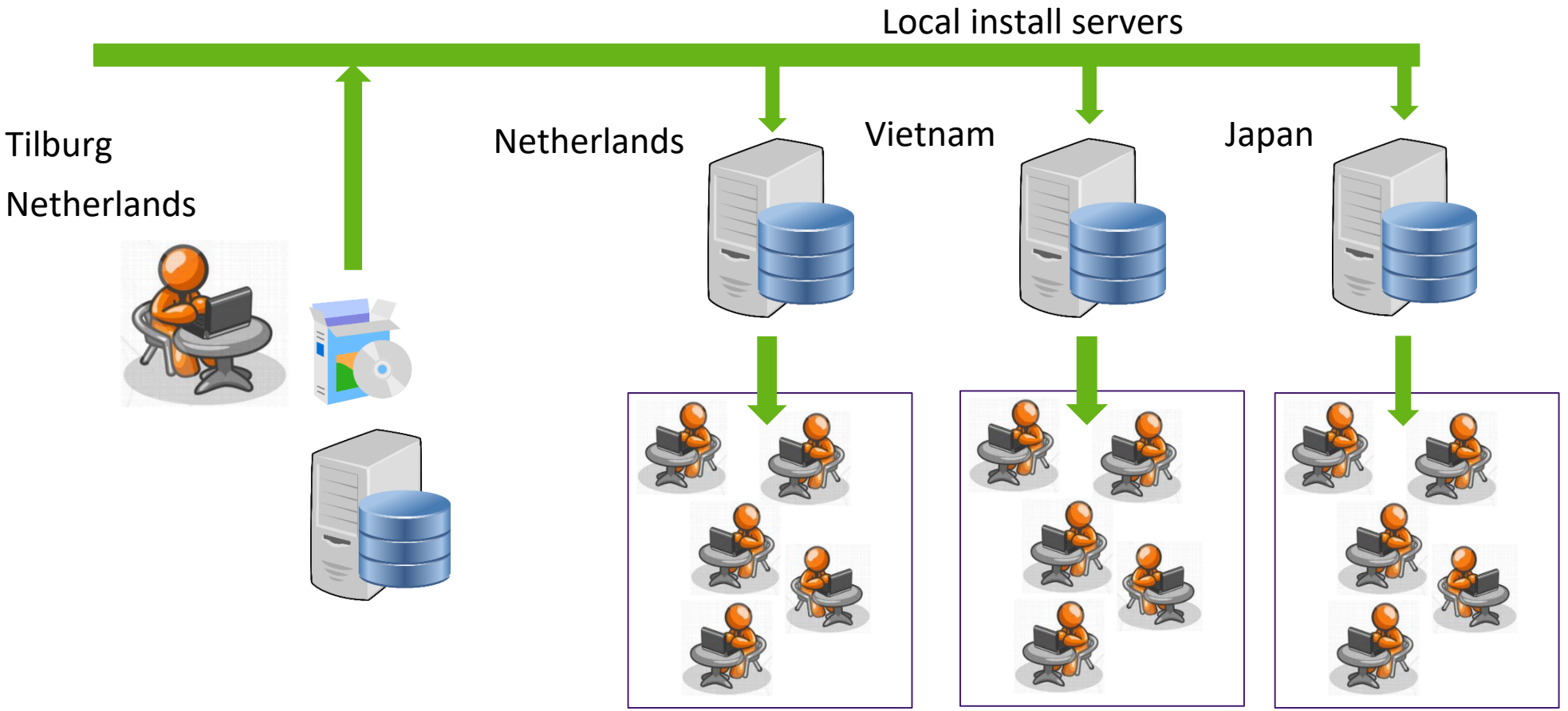
PS-CT/ICT

Maintain computer systems

Install Software

1. Upload to Software Server.
2. Install JAR on users' PC.
3. [Install Matlab runtime].

Local installation

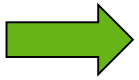


Drawbacks of the traditional design

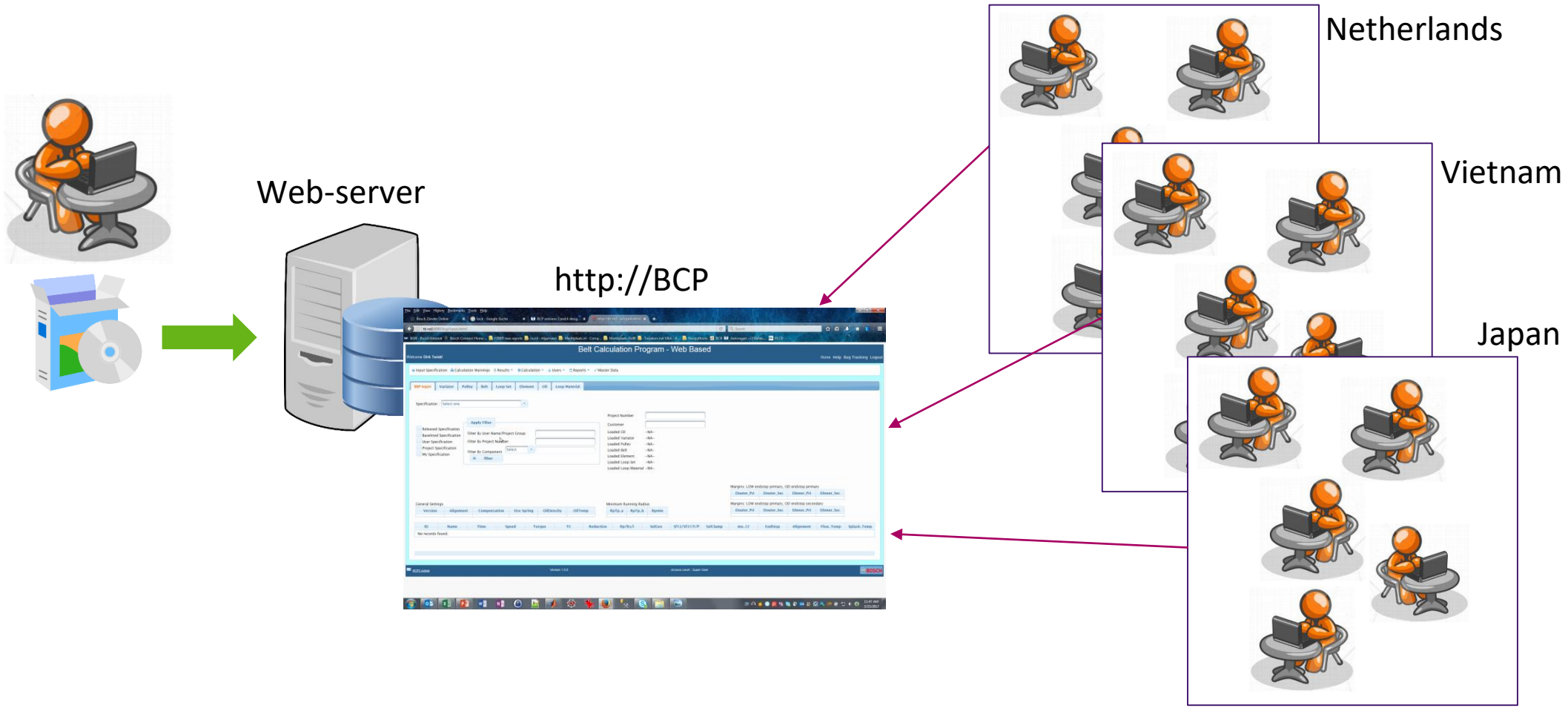
Complicated release process:

- Updates not synchronized due to the use of different install servers.
- Every user needs to have (correct) Matlab runtime installed.
- High maintenance costs (technical support).
- Sending data over the network is slow, so the performance is not acceptable.
- Changes to the Matlab code requires rebuild of the complete code.

After the second major release, it was decided to change the design

 Switch to a web-based approach

Web-based Approach



Improved Solution

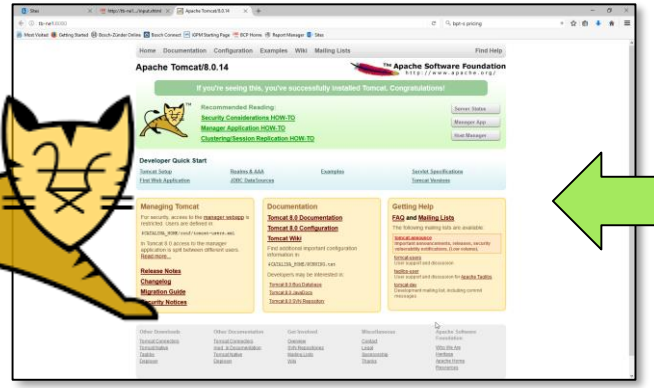
- Make the application web-based:
  - All required components run on a single server.
  - Only inputs and outputs are sent over the network.

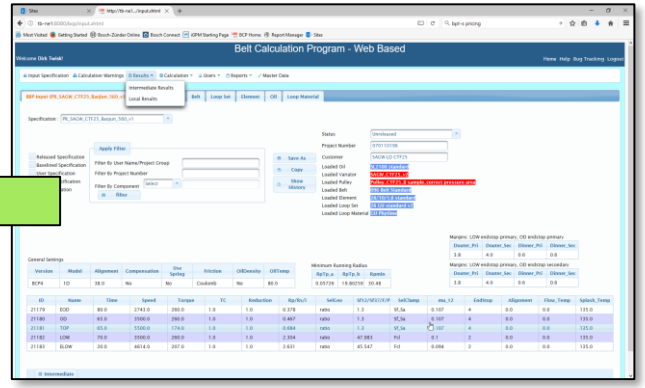
- Users do not have to install any software on local computers
  - The database itself is used to store user data and grant access to users.
  - Use NT login credentials

- Updating software is required at only 1 location
  - Synchronized updates of software and database.
  - Minimal disruption of service.
  - Maximum of 1 hour downtime for major updates.

Architecture

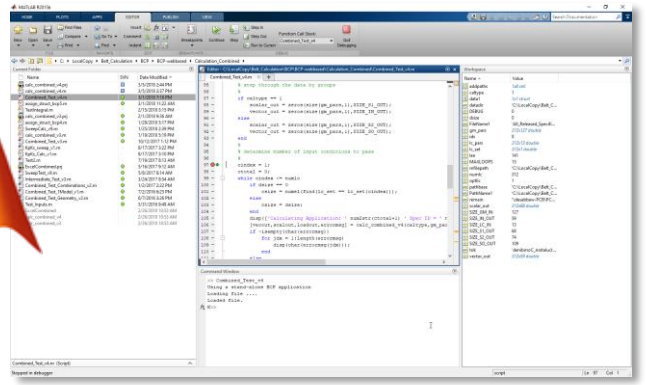
Tomcat

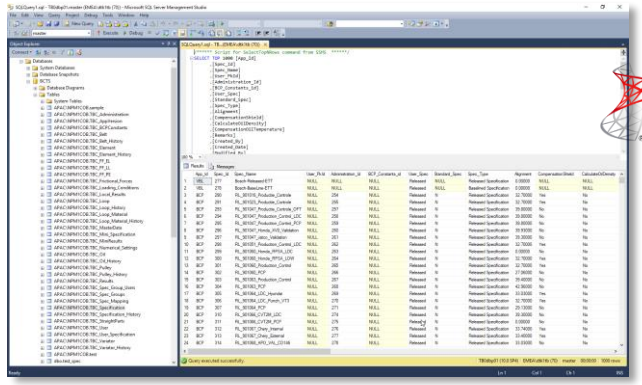




BCP Java applet

Matlab

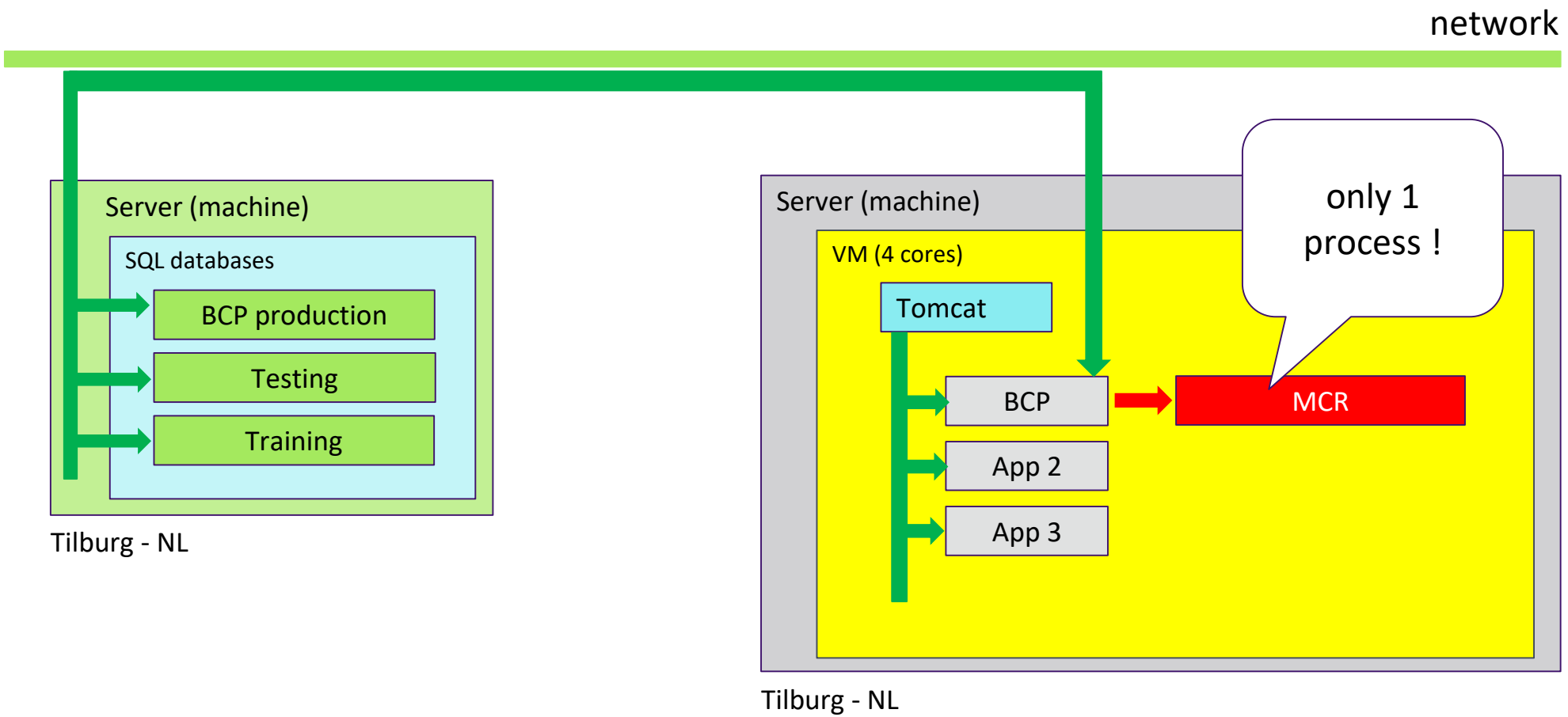




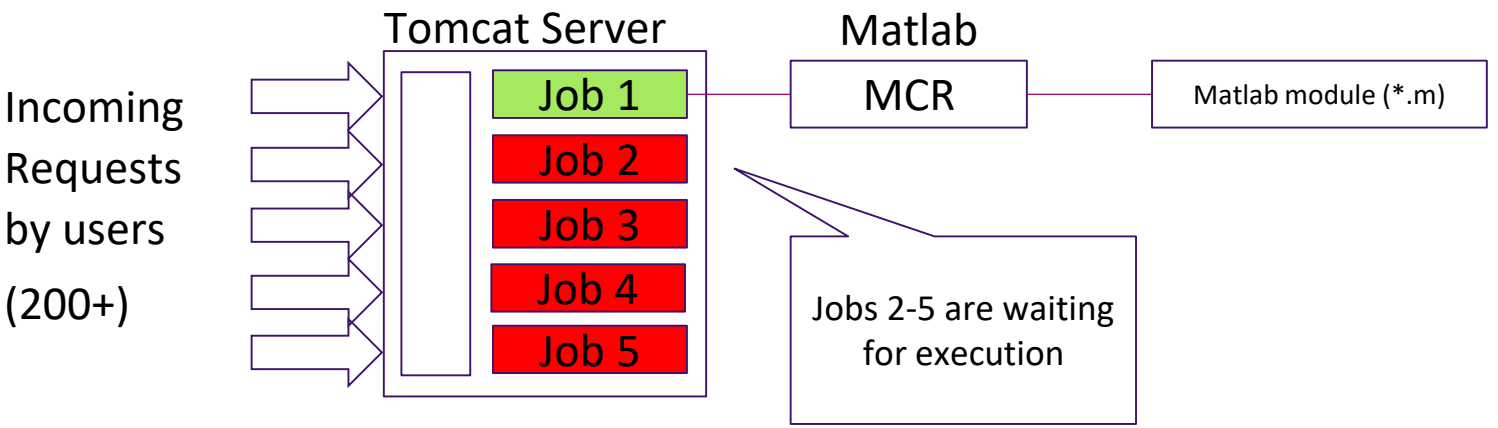
Microsoft SQL Server

BOSCH

Initial Implementation



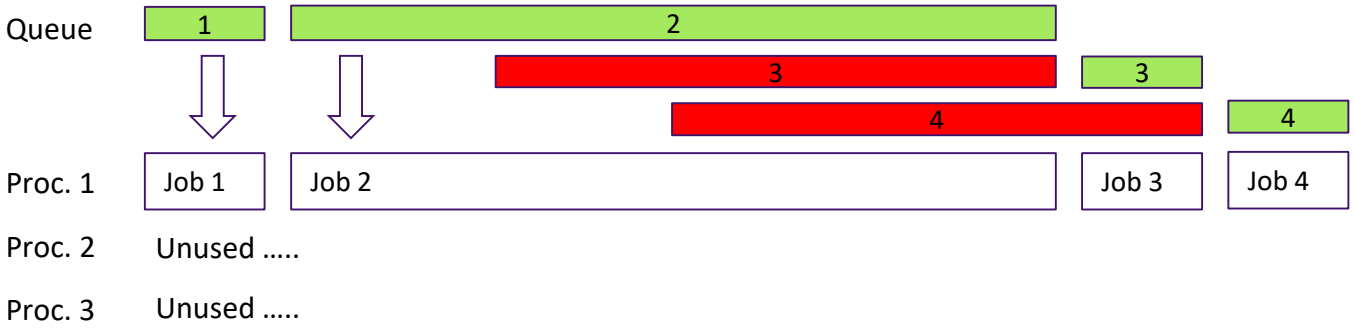
Limitations …



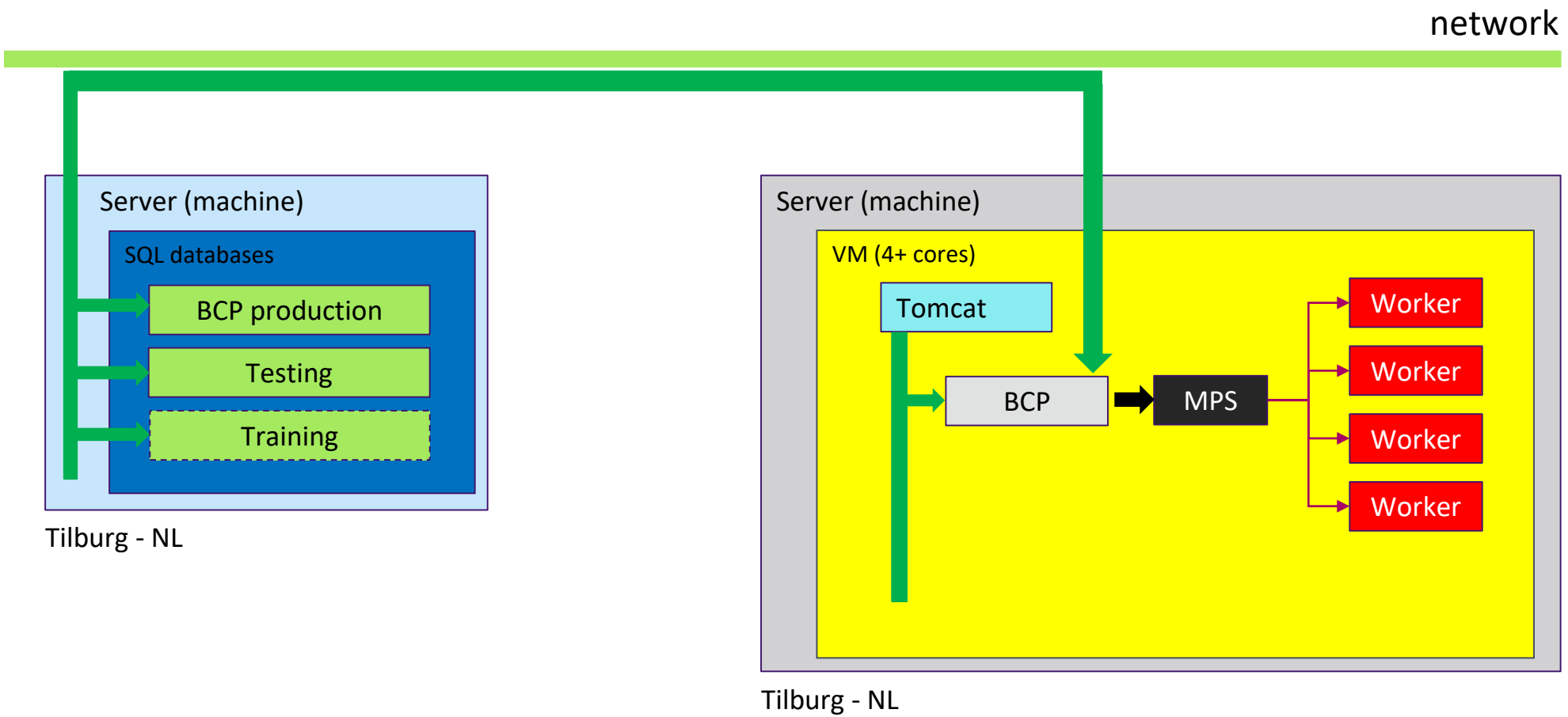
Calculation Times:

Shortest : 2 seconds

Longest : 24 hours

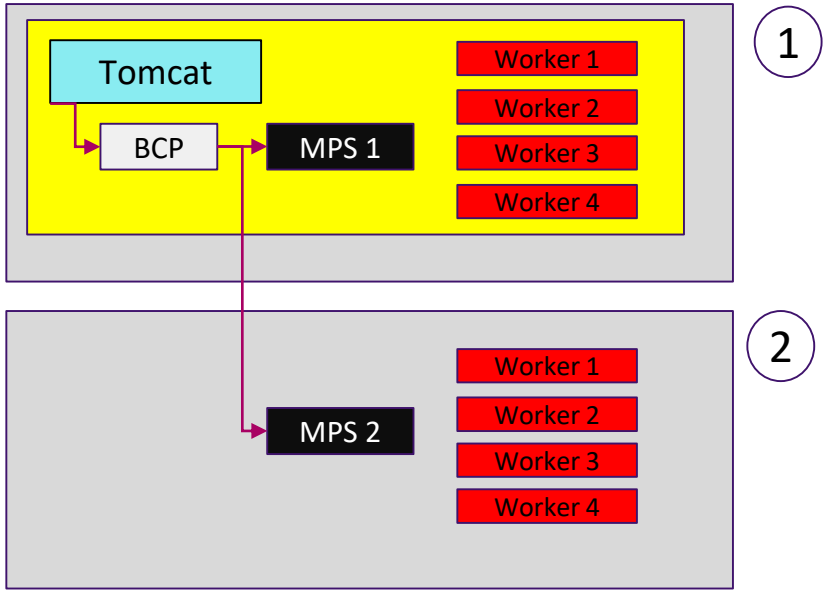


Infrastructure with Production Server – Final Design



Main Benefits of MPS

- Multiple Matlab jobs run simultaneously:
  - Each up to 24 hours per job (vehicle duty cycles).
- Scalable:
  - Add more cores to the server.
  - Assign different machines for different tasks.
  - Utilize available (unused) computational resources.
- Decoupled updating of main BCP code and Matlab code.
  - Define inputs/outputs between systems.
  - Independent updates of Java and Matlab code.
  - Log output is used to verify communication between the components.



Next Steps

Three developments:

1. Make existing standard programs web-based:
   - Model-Viewer-Controller type applications.
2. Create a library of common functions, allow calling from:
   - Java (web)
   - Excel
   - Matlab
3. Provide functionality to non-Matlab departments
   - Production, Quality, Inspection, …