ABSTRACT
The following paper presents a modular, groupware- and workflow based System called INFOFLOW. The system was designed to meet the requirements of a DIN EN ISO 9000 certified development and pre production plant. As a compromise between usage of standard software and a complete custom solution it is partly based on Microsoft Standard Office Software to increase end-users acceptance, supplemented by plugins and a self developed workflow engine, controlling the production flow, esp. exception handling and distributing relevant information between the several clients. INFOFLOW’s engine especially supports exception handling like activity related, predefined rework sequences or handling the scrapping of damaged parts. The system integrates workflow and information technology providing the users with relevant activity and order related information elements. The user interfaces are realized as electronic forms, embedded in Microsoft’s Outlook Web Access as public information store folders, representing the activities or People involved in the production process. These Web applications, called “electronic worklists” are created and distributed by the workflow engine. A mechanism to easily create and integrate user defined input forms allows the customization of the user front ends.

MOTIVATION
Today, workflow systems are widely applied in administrative business and organization as well as in the production sector. All systems supporting production workflows available on the market are characterized by the workflow being directed to large series with small modification rates. When having a small number of parts with high modification rates, for example: when producing single parts, a small series or performing R&D work. You have a more complex setup. Having more flexible work structures is required. But even in this field, there are good reasons for supporting workers by an adequate workflow control or the integration of information elements.

Supporting a pre production means handling exceptions nearly all the time, learning about the processes while doing several optimization loops - an approach, which can be seen as typical for a wide spectrum of product development in the pre production or single production phase. This comes from the fact, that -at that point of a product development cycle- neither all product parameters are clear nor do we know enough about the production process (especially when dealing with complex and new technologies like non silicon Microsystems). So features like process, project and activity related exception handling strategies and highly flexible order planning and monitoring are needed at this phase. Thus this can be seen as a sort of “permanent business reengineering process”.

In such “ad hoc” processes, the acquisition of measured data, resources, and remarks by the workers play an important role, as it is this information only that allows the flow of work to be optimized both technically and organizationally. This goal can be met especially when combining the workflow system with production oriented knowledge management concepts for storage and standardization of the measurement and workflow data in order to (partly) automatically generate the design rules for future production steps.

Our paper describes a workflow approach which allows the execution of ad hoc workflows [1], developed according to the definitions of our the DIN EN ISO 9000 Certification of a pre production and low volume production at the Research Center Karlsruhe’s Institute for Microsystems Technologies. Contacts to several SME’s in Germany but also to R&D departments of large companies have shown, that the requirements we had to deal with are quite similar to their needs in this field.

The structure of the paper is as follows. The next section summarizes briefly the “environment” our workflow system called INFOFLOW was built for. The build time and run time functions and the architecture of INFOFLOW are described in section 3. The validation of the System...
concept, based on the example of micro fabrication is described in section 4. Section 5 summarizes the approach, points out the problems we have discovered so far and gives a short outlook.

2.1 Related Work

2.1.1 Workflow Systems in the Production of Prototype Series and Single Parts

As mentioned above, workflow management systems are employed mainly in the field of office communication for the automation of defined organizational procedures. Another field of use is that of the production of large series, where the expenditure taken to model the workflow in detail is worthwhile.

As far as the production of small series is concerned, however, there have not yet been any adequate solutions that allowed for a flexible planning of the workflow, a documentation of the working steps and - which is even more important - the handling of exceptions at a reduced modeling expenditure.

One of the major intensions of INFOFLOW is to support a production oriented exception handling that can be best compared to the processes in a scientific-technological environment. The WASA Project e.g. –as one of the most interesting approaches in this field [2] is also based on a commercial workflow system (IBM FlowMark) by integrating decision support, additional tools for analyzation, additional user interfaces and database functionality.

The User interfaces are realized by WWW Browsers and Java Applets which makes the system platform independent. One of the major differences to the INFOFLOW system at the starting phase of our project was the fact, that (dynamical) changes in the workflow specification belong to all workflow instances – a circumstance that prevented the usage of the system when analyzing process parameters and monitoring machine variations in relation to the order specific specifications.

2.1.2 Workflow-based Order Management at the Micro fabrication Division of the Institute for Microstructure Technology (IMT)

While certifying the IMT according to DIN EN ISO 9001 [3], first steps were taken in 1997 to support the complex planning, management, and control tasks expected by the use of software tools.

It soon became clear that the standard Enterprise Resource Planning (ERP) Tool SAP R/3 lacked flexibility in meeting the special requirements of the production of single parts or small series and that their configuration would require too high an expenditure.

The general order management from the customer request to the Product distribution is shown in Figure 1.

![Fig. 1 Order Processing at the Institute for Microstructure Technology](image)

As a compromise between the use of commercial standardized systems and the necessary customization to the special requirements of preliminary and small series production, the INFOFLOW system was developed. It supports the workers in planning and fabrication, supplies up-to-date information at the right time and place, and helps the workers in managing their tasks more easily and rapidly.

INFOFLOW is characterized by a number of specific extensions and the consistent use or adaptation of standard components. This allows an easy and cost effective integration in the existing Software Environment – which is the Microsoft Office product family at the Research Center in Karlsruhe . Nevertheless the combination and extension of the MS Office components covers the functionality of most standard workflow systems.

2.1.3 Delimitation to Microsoft’s Workflow solutions

When developing a Workflow system, mostly based on Microsoft Product enhancements, the question might come up why not use an enhancement of Microsoft’s Sharepoint Portal Server [4] as Workflow Engine (or the Access Workflow Designer)?

The simplest and most honest answer to this question is: At the beginning of the INFOFLOW project neither Sharepoint Portal Server nor MS Access Workflow Designer were
available. Share Point Server final release is available since beginning of 2001.
Comparing the three approaches under the workflow management aspect—as we have tested Sharepoint Portal Server so far—we can see, that the application mainly focuses on sharing documents in teams (especially document/content management, including aspects like version management, collaborative work). To reach this goal, workflows can be defined, but only by means of simple, completely predefined release sequences. The treatment of complex (process-dependent) sequential and parallel workflow logics seems not to be implemented in the standard version.
The INFOFLOW “Workflow Manager” approach focuses on the workflow control aspect, based on production related data and (if necessary) application data, both stored in a relational database (see chapter 2.4).
Information elements (for example: specifications) are not managed by INFOFLOW by means of document management. The Integration of documents is focused on the support of the employee at the different operating levels by providing relevant information according to the actual activity and the actual order type (if available), which is a mix out of stored documents and reports generated at project runtime.
Both systems are based on a user role concept. INFOFLOW’s uses a self implemented concept for process definition, order planning and monitoring. The MS Exchange User Role Mechanism has been integrated for the administration of activities (see chapter 2.3) The Sharepoint Portal Server also provides for a user role concept, based on Microsoft’s Active Directory technique.
Result: After a first, short test phase we can see, that both systems could supplement each other. Sharepoint Portal Server could be used for the document management as well as the handling of well-structured procedures like the treatment of a customer’s request during the acquisition phase. It could provide the correct and actual versions to the INFOFLOW Information system. INFOFLOW is more process oriented, offering maximum flexibility during the planning and production phase and offers many features in that field (see below).

2.2 Special Requirements To Be Met by INFOFLOW

It was the primary objective of the development work to reach a higher transparency of the work processes in planning and execution by an online acquisition of all process-relevant data. This includes:
- Partial automation of standard processes
- Implementation of rule-based processes (thus supporting quality assurance measures)
- Acceleration of internal processes
An independent operation system resulting from the development of www-based user interfaces is aimed at reducing the costs of integration in an existing electronic data processing environment and decreasing the administration expenditure.

In view of the decentralization of production, such a system has to support distributed fabrication locations (for the IMT: BESSY in Berlin and ELSA at Bonn university) e.g. by means of Virtual Private Networks.
To manage orders while using processes that can hardly be automated, it is necessary to constantly assess the current state of development in order to recognize and influence mis-developments at an early stage. For this, data on the current state of the orders and the respective evaluation tools have to be available.
Frequent modifications in the preparation of non-standardized work processes require constant updating of work instructions, process parameters, etc. The worker should be able to use information elements, such as history functions, work-related instructions, work-related inputs of measured data, etc. without any additional search or updating expenditure being required.
To increase the acceptance of such a system, it should be integrated in the usual work environment and supply all relevant information items at the user interface.

2 IMPLEMENTATION

The INFOFLOW approach is mainly based on standard software extended by additional modules (Fig. 2). The system is controlled by a newly developed workflow manager.
The major user module for planning and supervising is based on the Microsoft Project 98/Project 2000 planning tool. This tool has been extended by INFOFLOW configuration, planning, and monitoring functions. Another important module is the groupware tool of Microsoft Exchange/Outlook. Various forms, the so-called electronic operation cards, have been added to the Outlook Web-Access interface. Storage takes place by means of relational database systems.
These components shall be described in more detail in the sections below:
2.3 Workflowmanager – Handling Errors or Exceptions

The workflow manager module is the central component of the INFOFLOW system. It is implemented as a Windows NT service, which allows for its complete integration in the operation system environment. During the runtime, the models defined are executed (enacted). The INFOFLOW concept uses the Workflowmanager together with the Exchange Server for this purpose. For the communication and dialog with the workflow participant the Internet Information Server (IIS) is applied.

- **Basic Functions**

Its basic functions consist in controlling the processes stored in the runtime database based on the rules stored in the database. For this purpose, the workflow manager – using a standard outlook profile - generates several types of messages, evaluates incoming messages, and stores the accompanying information and process data. The usage of MAPI messaging allows us to attach process related data and the definition of several message classes where different electronic forms can be attached to.

A plugin allows for the database synchronization of the INFOFLOW runtime data with the planning and monitoring modules for status administration of the various fabrication orders related to the order, etc.:

- **Support of Rework Processes**

One of the major goals of the INFOFLOW approach is system support in handling errors or exceptional cases as proposed in different reference architectures [5].

If the employee in charge of a process step realizes that the task cannot be handled according to the specification or the value of measurement data is out of range, he has to press the “NotOK” button. The main workflow sequence is stopped and the system offers the following options - depending on its configuration to the related supervisor who is notified by the workflow manager. The different strategies are shown in fig. 3 where the processing of an internal order is visualized.

- “exception” handling described by conditions:

In certain cases the handling of a production exception can be described by logical operators (e.g. a measurement value is out of range and the measured value is not more than 2 microns out of the tolerance. Because the device is an experimental device the). From a production point of view we would be in an exception situation because we’re out of tolerance. however from the business process modeling point of view we have no exception case, because it can be described by conditions. In this example case the rework mechanism can be automated by predefined rules / conditions, stored in the runtime database. This function is usually used, when an activity which is well known and which returns determined values is running.

- “hand triggered” exception handling:

In most single production “real world” cases an automation is inexpedient and a supervisor has to decide, how an exception has to be handled (could be compared to an event-handling). The Workflow manager sends a message to the supervisor containing all Information gathered so far. The form is similar to the electronic operation card but is enhanced with several check buttons, representing different strategies, allowing the supervisor to trigger an appropriate activity.

INFOFLOW supports three different types of exception handling:

- **scrapping:**

In this case, the Workflow Manager notifies all people that are involved in the project about the workflow status and creates a new instance of the actual workflow. If a lot size production is concerned, the internal order is divided in two order with an identical order number, but different lot size number and only the amount of damaged parts will be restarted. The decision process is supported by a standardized organizational workflow.

- **inspection or proving exception:**

The supervisor is notified and decides (after consulting the customer) to allow for a continuation of the actual internal order. In this case, the workflow only is broadened by the
Supervisors decision activity and the redefined target values must be handled.

- start rework process

In addition, the workflow manager handles finishing processes (rework), in charge of the project or the activity, simultaneous indicating possible rework cycles.

The supervisor decides to start one out of maximum three predefined rework workflows, accepted by the quality management, which can be related to the activities. Until the rework workflow finishes and has -again- returned the result “OK” or “Not OK” the internal order is stopped. If the result of this finishing process is “OK”, the order sequence continues, if it returns the value “Not OK”, one of the other cases takes place.

INFOFLOW allows for the workflow related definition of three types of supervisors which shall be notified in case of an exception: activity related supervisors, order related supervisors and a global supervisor.

2.4 Process Definition and Monitoring Module

The modularity of INFOFLOW allows for the integration of different planning tools and types.

After having tested a few commercial planning tools and having created a self developed planning tool, we decided to integrate and to adapt MS Project from Microsoft.

There were several reasons, which led us to select this tool. MS Project’s principal planning function is quite intuitive to understand and to learn - an essential requirement when wanting people from the enterprise shop-floor to use such a system. It is widespread at the research center and easy to integrate in a Microsoft system environment.

It’s main restriction, which also limits the usage of the INFOFLOW system, is the amount of projects that can be opened in parallel. Because the resource management is based on this “multi project” opening functionality the handling of more than 60 projects in parallel does not work properly. It is possible to display all internal orders related to one custom order, but not to display all custom orders not even in a more abstract form on a more generalized level.

The basic version of MS Project contains the major functions for simplified planning. The adaptations made are therefore aimed at using these functions, at integrating them in the total system together with new modules, and at adding workflow-specific features and micro system-specific requirements. These new functions shall be presented below using the INFOFLOW extension menu as a guideline:

2.4.1 Configuration

The configuration menu contains the following major operations:

- Definition of Activities

Here, activities are defined, persons authorized to execute them are assigned, references to activity-specific information elements are added, and the person responsible for the activity is determined. Furthermore, various activity-specific information elements can be assigned. Also logical constraints, like different specifications for the various order types can be assigned.

In certain cases it might be useful to attach different message classes to the activity, i.e. to focus on specific aspects of a proving step that can not be covered by the standard measurement input form

- Definition of process templates

A template in the INFOFLOW system is understood to be any process that serves as a model of representative orders, standard operation cards, etc. This type of process has to be defined anyway and is attached to the different specific workflow types in a second step. Parallel and sequential processes are supported.

- Definition of standard processes

This menu allows the redefining of templates to standard processes. In connection with the standard processes, the respective standard parameters, i.e. given by the quality management, can be defined.

- Administration

Various Forms allow the definition of user roles and configuration of application specific features

2.4.2 Resources

INFOFLOW uses the resource planning function made available by MS Project and other planning and simulation tools. In addition potential resources are assigned automatically to activities according the quality managements requirements for peoples qualification.

2.4.3 Execution

- File/Store Internal Production Order

In a first step, the planner files an internal production order by linking the data of the customer order to the representative or standard process and adding specific details, such as the respective layout number. The system generates an unambiguous identification number for the new workflow.

In a second step, scheduling and fine disposition are carried out by the fine planner, who also gives the order-specific details. The planner is supported by the underlying information system. The planning data are stored in the project database together with the order data (Fig. 4).
Fig. 4. INFOFLOW Extensions, implemented in MS Project 98

- Start Workflow
At first, the data is transferred from the project database to the runtime database. Then, a message initializing the workflow manager is generated.

Monitoring Mechanisms/Report Functions
INFOFLOW allows an automatic query of the status of the individual customer or internal production orders, including possible rework processes. The orders can be evaluated using the analysis methods available in MS Project. Via the information system, comments or remarks made by the workers can be retrieved (Fig. 5).

The individual production orders can be printed out by the report generator in the form of individually definable reports, being generated by MS Access macros.

Rework Activation
When the system – triggered by the supervisor or automatically - generates a request for a rework, a message is sent to the order planner or the rework activation mailbox, containing a MS Project template with the relevant order information. The order planner has to “post process” the template by realizing the capacity scheduling and key date scheduling for that –unexpected- order.

2.4.4 Information Elements
The information elements, such as work and test instructions or specifications, are assigned to the activity or type of order and made available at the respective points of the planning and production process. INFOFLOW supports all usual documents formats, such as HTML, Word, and PDF. It also supports many multimedia formats. An integrated video conferencing functionality allows – if a web cam is available- web conferences.

2.5 Groupware System
Standard Groupware extended with activity and order specific Forms
The groupware system plays the role of the central communication component of INFOFLOW. According to the constraints mentioned above, we integrated MS Exchange as commercial groupware system. MS Exchange offers some specific extensions that allow for an easier handling of the Mail elements.

Here, the presentation of the internal orders in activity related files takes place. The files have the form of “mailbox elements” realized in the public folders workspace. These mailboxes contain the still open orders related to a current activity, represented by MAPI messages. The MAPI messaging objects include general information about order and the Activity type.

The activity type also contains information about the MAPI messaging class attached to it. This allows it to switch between several GUI-forms.

By using the message information the activity related orders can be ordered by individual aspects like priority, order number, customer, etc.

The open concept allows the “external” generation of messages by the workflow manager or MS Project as well as the modification of the messages located in the system. For transmission, the methods and safety concepts as provided by Exchange are used.

The generation and administration of the folders is completely integrated in the configuration module of the MS Project INFOFLOW-Extensions

Microsoft Outlook Web Access - the ”Electronic Operation Cards” Access System
MS Exchange has a web interface, which allows access to the system via web browsers independently of the platform. Hence, it is excellently suited for use as a common
communication base in a heterogeneous work environment with distributed locations.
INFOFLOW uses self-defined electronic forms and the access to these messages via the Outlook Web Access authorization system. (Fig. 6).

The profiles managed in MS Exchange support a user-oriented and group-oriented access system that is controlled via the mailbox display. On this basis, the authorization to execute a certain activity is limited to those persons that have been trained for this purpose.

The user logs on the respective system and opens one of the "mailboxes" (corresponding to an activity) of the user’s group. Each of these mailboxes contains messages that can be given priorities in the course of production planning. Via a configurable display table, major order information on all open orders can be displayed.

The electronic operation cards are set up in a modular manner. Depending on the activity, the electronic forms may vary within a production order, as mentioned above. If a basic display is applied, certain display elements can be faded in or out only.

An electronic operation card typically consists of the following modules:

- Order headline data
- Information elements with the work/test instructions, order-dependent specifications, history function, and link to user programs, e.g. data acquisition
- Information fields of/or order management
- Status fields of the operation card with activation of the freely definable rework functions

An additional password check ensures that only authorized personnel is allowed to finish the task.

2.6 Databases of INFOFLOW

The database system of INFOFLOW is divided into four main segments:

- Standard processes
- Content management
- Application-specific data
- Product related Information

A fifth Database for MS Project is synchronized with the databases mentioned above by the workflow manager plugin. Each of these four segments may be assigned to one of the integrated standard components. If one of these tools is exchanged, the entire database system remains unaffected. It is only necessary to adapt or generate the corresponding library file for this new module (Fig. 7).

Via the ODBC (Open Database Connectivity) interfaces, INFOFLOW can be adapted to most commercially available database systems.

3. VALIDATION OF THE INFOFLOW CONCEPT, BASED ON THE EXAMPLE OF MICRO FABRICATION

The INFOFLOW concept was developed closely in line with the requirements specified by the Micro Fabrication Division of the Institute for Microstructure Technology. Hence, a number of the functions described above resulted from the daily workflows encountered there. However, discussions with other medium-sized enterprises demonstrated that this principle approach is applicable to many types of enterprises. Therefore, the following section briefly covers those IMT specific features that have not been integrated in the system for the sake of a general approach.

A major component to support IMT-specific requirements is the revision management of layout numbers. Their logics have been automated and integrated in the INFOFLOW extensions.

The possibility to generate production-dependent reports and display elements in INFOFLOW has been implemented for three types of operation cards: Production of semifinished products, mask production, and production of master parts.

At the moment, first production-specific application programs are being developed parallel to the commissioning of the system. This means that exemplary machine data are integrated for the automatic management of individual production steps.
4. DISCUSSION AND OUTLOOK
While most of the functionality described above is implemented and tested since 2000, a lot of work has to be done in the field of automated generation and storage of measurement input forms, using the meta information of the application database and the OOA Model. The structuring of the process related information in the development phase which is collected during the workflow-execution will be of great benefit for further process optimization. The analysis of the development and the exception handling strategies will hopefully reduce the time to develop MST products.
In more detail we also found out that the flexibility provided by the system in an exception case is too high to be handled in an appropriate manner. So some reengineering of the rework functions and related workflows towards a simplification of the rework directives has to be done.

The system performance actually is limited by the use of MS Project as planning and monitoring system. Our experience with MS Project ´98 has shown, that the handling of more than 60 processes in a master project file in parallel doesn’t make sense. This limits the monitoring functionality to the visualization of one customer order (which should normally consist of less than 50 internal orders, including all reworks and scrapings). The resource planning must be also done in a different system.

We found MS Project to be insufficient for our needs. We are now searching for a planning and simulation module whose basic functionality is as flexible and intuitive as provided by MS Project, but which better fits our (increased) performance requirements.

The data obtained by means of the system shall be used for the planning and analysis of the processes. For this purpose, the “Income” business process simulation by Promatis Company was linked to the system in a prototype manner. By means of this tool, commercial and planning aspects, such as production bottlenecks, can be analyzed. Analysis and planning tools for the evaluation of the technical data collected are considered, but require the electronic acquisition of sufficient measured data first.

This area increasingly gains importance in planning and production. Reason for that are the increasing complexity and interdisciplinarity of process chains or the introduction of new organization structures in the enterprises like virtual enterprises.

In a separate project web based process- and production oriented KM-Tools are under development, allowing us to derive process-independent, activity related design information from a project allowing us to define design rules, a challenge especially during the functional model- and prototype-production phase.

The same information will also be used to define conditions for an further automation of the processes.

REFERENCES