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COMPLEX ICAR - EFFECTIVE RISK MANAGEMENT INSTRUMENT AT CREATION AND OPERATION OF SPACE SYSTEMS

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Abstract

The report presents a detailed exposition of the basic approaches to solution of risk analysis problems including original methods developed by the authors for unbiased statistics estimation of partially registered data selection, schemes and results of stochastic verification of the developed algorithms.

Within the framework of complex ICAR for the first time the risk management technology has been improved and developed into a uniform information technology for project management at space- rocket engineering including configuration, quality, reliability and cost management. This structure is integrated with international project management technology and can be applied to risk analysis of complex programs on future space systems development and for training experts and chiefs, participating in international projects.

Introduction

Risk management is aimed to minimize total expenses on creation of spacecraft with specified characteristics in view of possible losses connected with infringement of obligation terms, emergency conditions at tests and start-up, and also in view of environment and third persons damage.

The aim of development of the interactive complex for risk analysis (ICAR) is to create an instrument effectively realizing science intensive technology for analysis and risk management at space-rocket engineering (SRE) design and application, which comprises:

-uniform order of SRE creation and operation determined by Specifications and State Standards of Russian Federation;

-methodology for decision substantiation under uncertain factor conditions approved within the framework of industrial systems of reliability and safety assurance;

-allocated database on results of control, tests and operation of SRE units and their elements, accumulated at leading research institutes, design bureaus and factories;

- methods, algorithms and models (simulation) for assessment of efficiency, safety, losses at SRE creation and operation.

Scheme of the report: **figure 1.**

We have Know-how base

Unified creation order system: (**figure2,3)**

• life cycle: stages, points, decision;

• program requirements;

• specifications: designer requirements, technological requirements, operational requirements.

• data on results {knowledge}

• retrieval: failures, mean times, reserves, parameters;

• evaluations: reliability, safety, action efficiency;

• predictions: guarantees, losses, risks.

(**figure 4)**

• Methodology {decision making under uncertainty}

• general scheme: object, analysis; (**figure 5)**

• strategy principles guaranteed, fractional, flexible; ;(**figure 6)**

• analysis instrument: methods, models, algorithms.

Key problems of reliability and safety assurance methodology

Reliability and Safety Program Plan execution makes it possible to coordinate efforts of all the departments and services at contractors enterprises during each space system life-cycle phase.

Development test program realization in

accordance with test norms to accomplish a comprehensive experimental perfection, verily standard and nonstandard functioning modes, detect ’’weak” points and eliminate failure causes.

Reliability and safety continuous (multiple) control helps to prevent failures at the most earlier phases of the space system life-cycle.

Realization of reliability improving program plan makes it possible to support and improve reliability and safety of space system elements, improve production quality, extend operation terms.

The lower discussed classification of estimation problems and reliability control embraces both extreme and interim variants. But it is worth minding that interim variants of reliability requirements experimental-computational and stepwise confirmation make estimation problem qualitatively more complex, to say nothinq of processing planning problem complexity. In that case space system structure synthesis problem and that of advancing-through-testing planning become interrelated and interdependent.

The basic classification factors for spacecraft reliability estimation and control problems to be discussed are:

- factor being estimated;
- estimation type;
- a priori data registration form;
- estimation model;
- a priori information representation form.

A problem of method selection to solve every basic estimation problem may be expressed as problem of the best reliability estimation considering requirements for statistics accuracy (e-criterion), model adequacy (a-criterion) and algorithm validity (71-criterion)

1. We propose risk management instrument (ICAR)

- Complex structure
- facilities: PC, networks, visualization;
- data: norms, engineering documentation, technological software: standards, special, debugging.
- Activity stages
- task identification: scenarios, decision-makers persons carrying out analysis;
- scenario run: data, models, algorithms verification;
- studies researches: analysis, synthesis, decision.
- Examples of results
- strategies efficiency;
- non displaced evaluation algorithm;
- risk of «Mir»-station submersion

2. What will be result? (interactive risk management technology)

- Risk management of space systems
- Risk management of regions, of sectors industry
- Training (Analytics and Decision-Makers)

Conclusions

The basic novelty and technological progressives of the offered solution are based on the usage of modern software and hardware in order to provide active participation of several Persons Carrying out Analysis (PCA) and DecisionMakers (DM) located in an operative service area of chosen communication system (Internet, Intranet, network).

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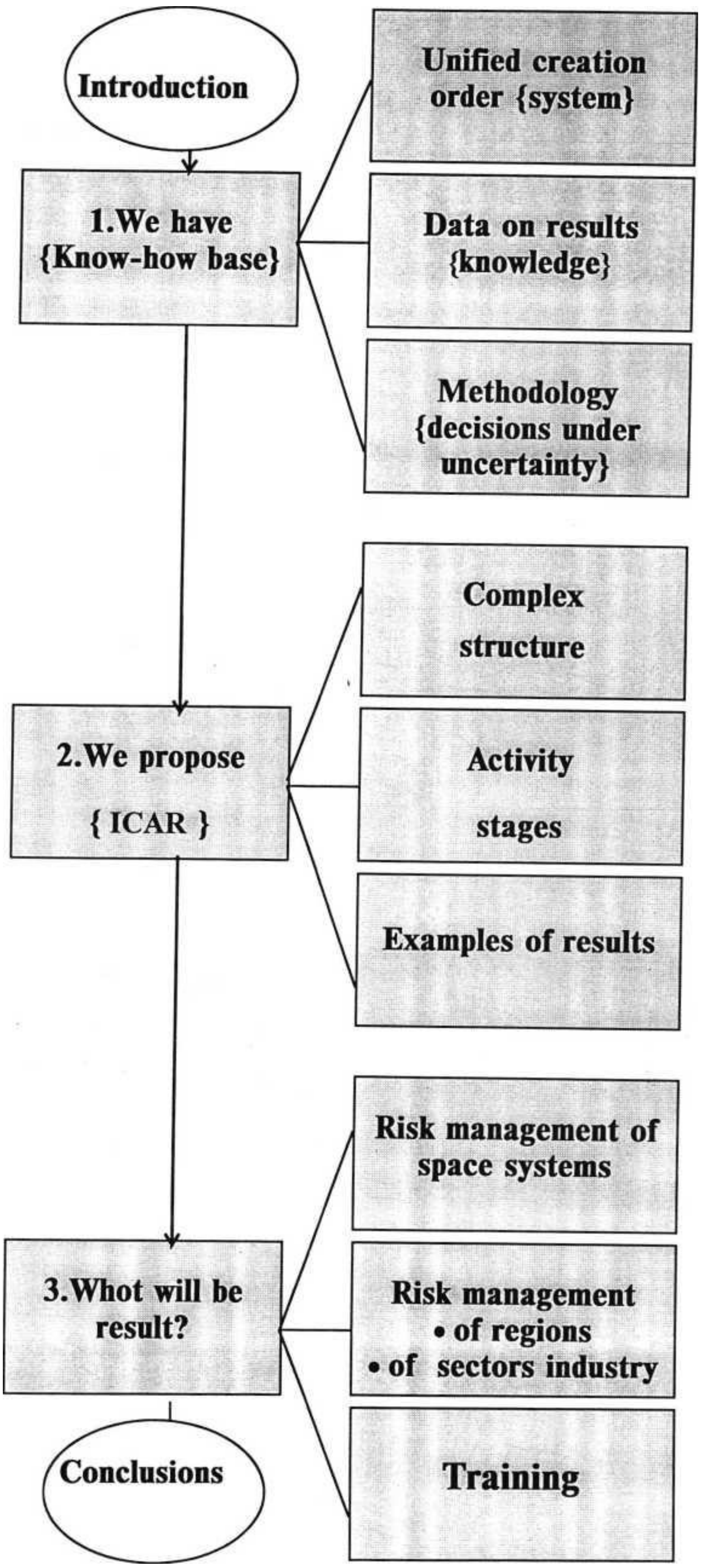


Figure 1. Scheme of the report

Figure 2. RELIABILITY AND SAFETY ENSURING

Problem and Tasks

- **Space Technology Peculiarities**

Large investments
Complex systems and elements
High reliability and safety requirements
Necessity of conjugating essentially different systems
High initial level of uncertainty

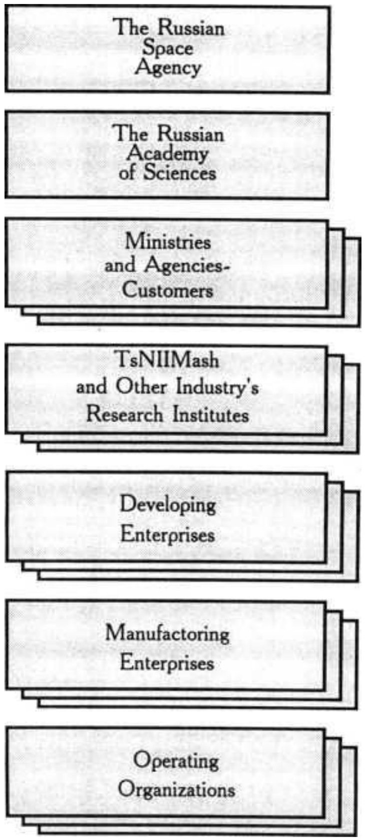
information basis of reliability and safety assurance system in the space technology industry.

Tasks

Organization of reliability assurance service, information (reporting) system Development of investigation and validation of reliability decision making Reliability instrumentation and norms creation

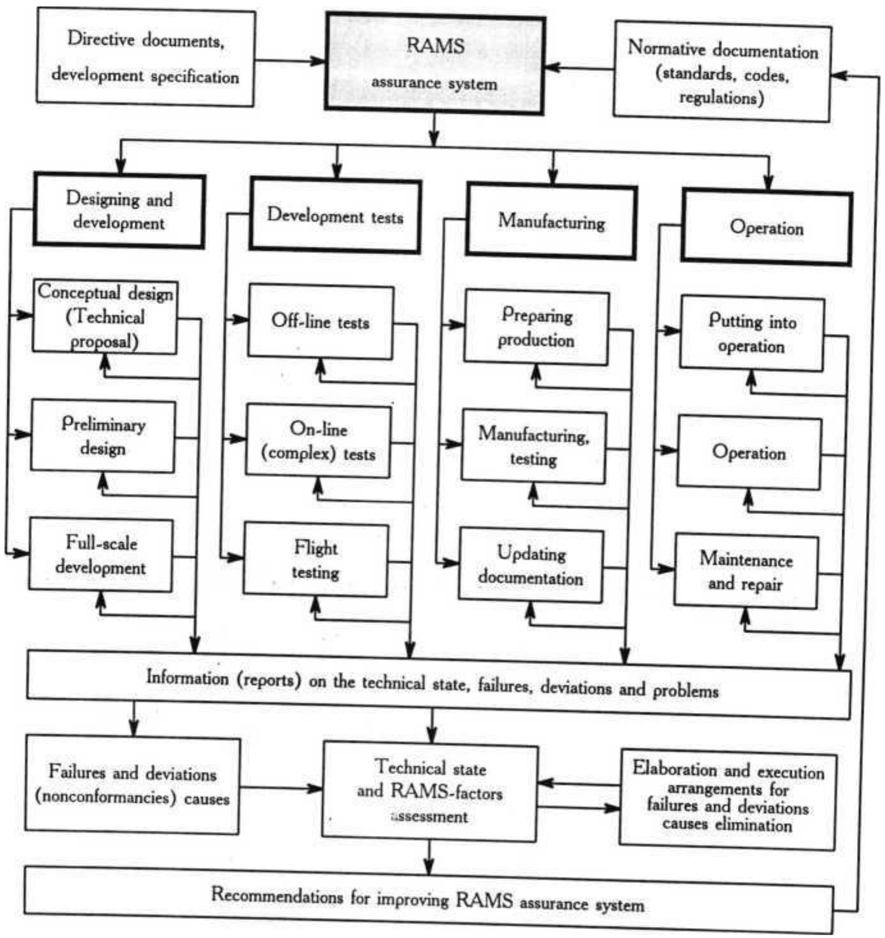
The Structure and Participants of the Reliability

Participants of Acquisition Process



Problem

Creation of organizational, methodical and



Assurance System

Problems being Worked out by Industry Research Institutes and Russian Academy of Sciences

- **space program making up and validation;**
- **elaboration and concurring development specification requirements;**
- **scientific and technical supporting;**
- **critical review of designs;**
- **failure mode and effect analysis;**
- **taking part in elaboration and execution of reliability and safety program plan;**
- **participation in development tests;**
- **drawing an evaluation conclusion on the space system readiness for flight test and reviewing its results;**
- **flight test supporting;**
- **support of the manned space systems operation;**
- **improving norms and standards.**

Figure 3. SPACE SYSTEM ACQUISITION PHASES

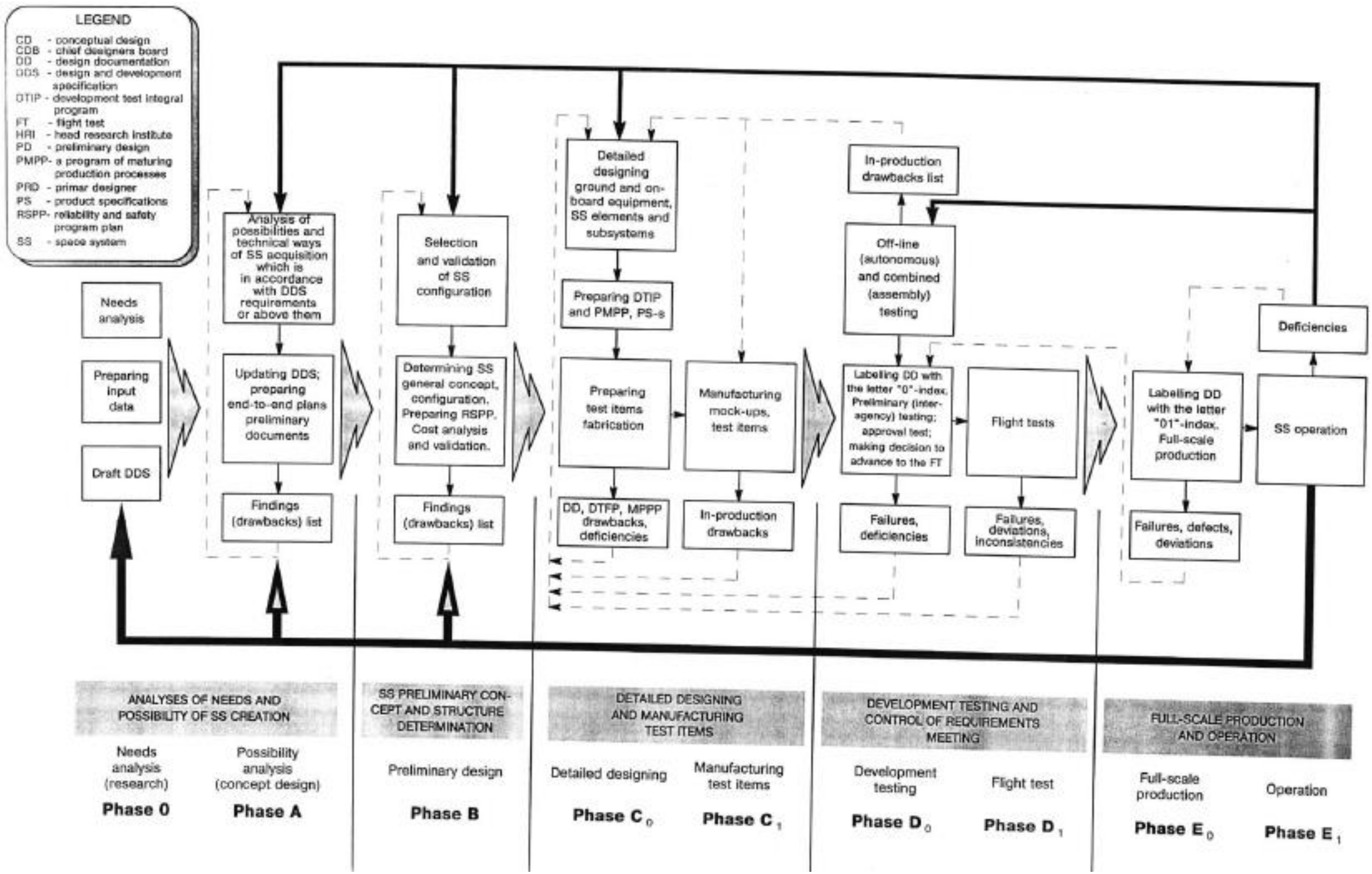
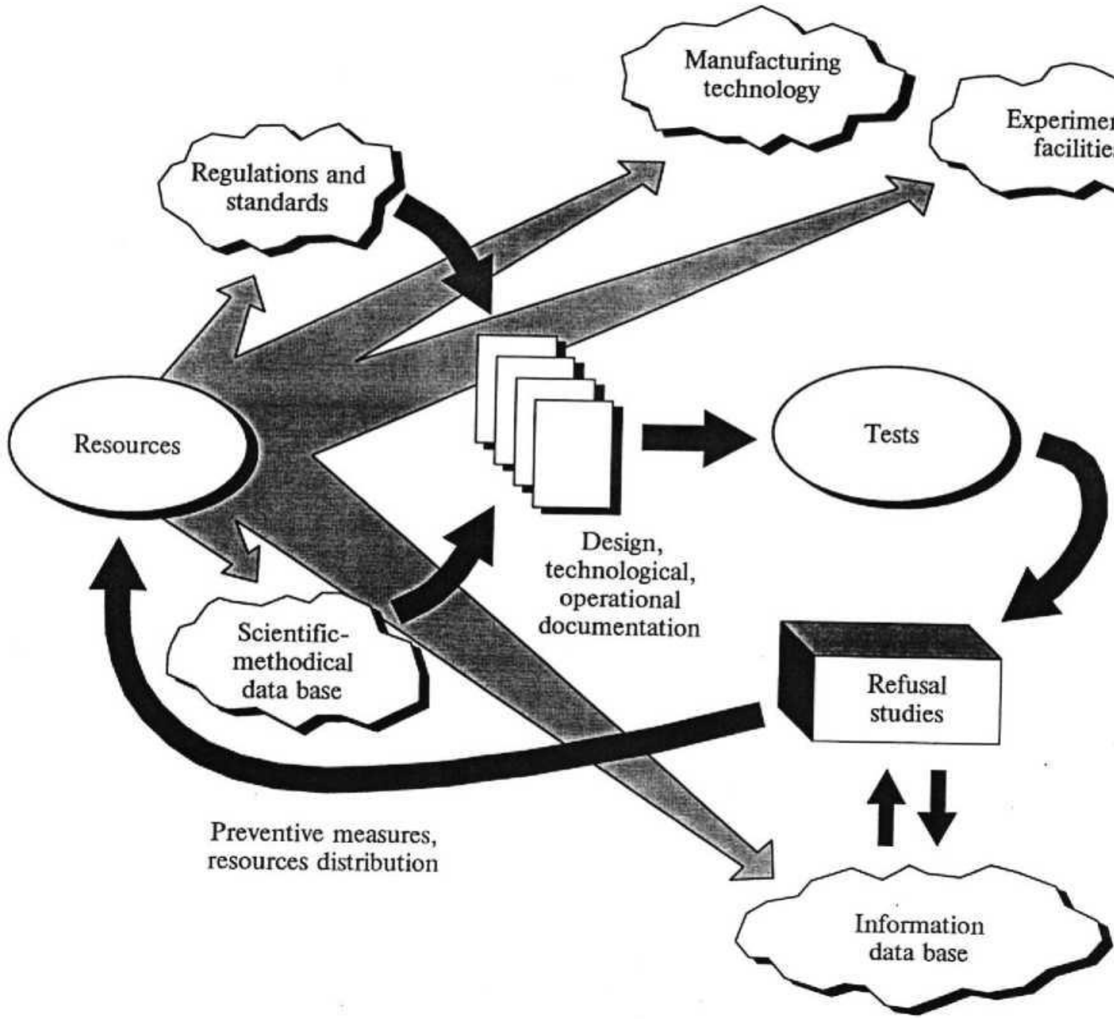
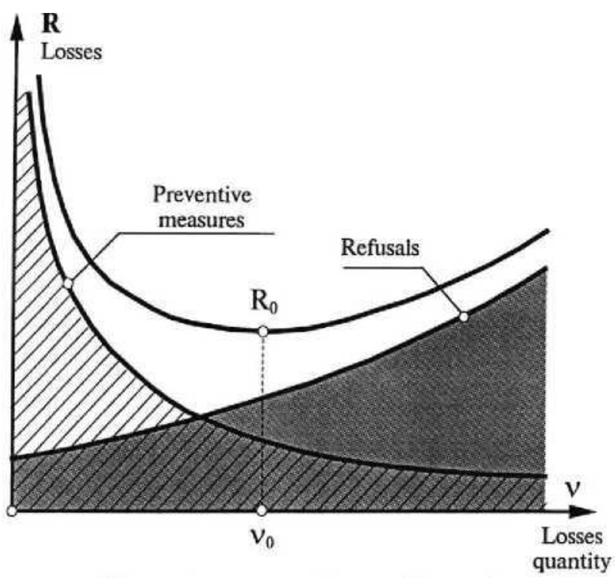


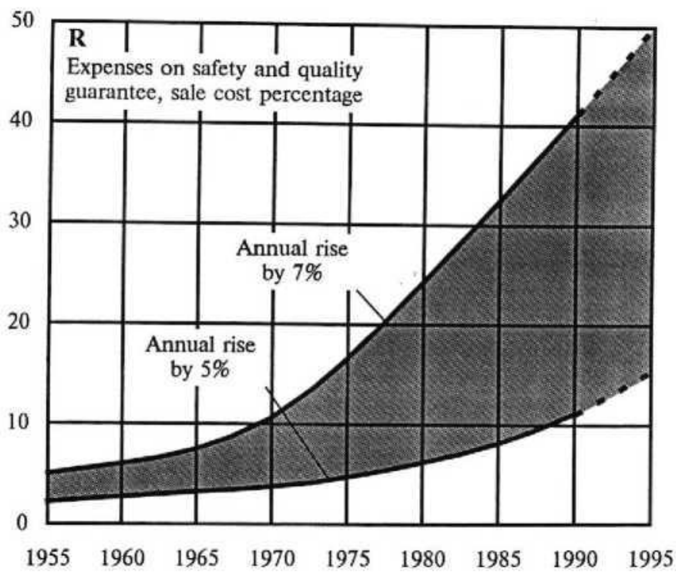
Figure 4. GENERAL MANAGEMENT SCHEME



Resources distribution forms management efforts



The system guarantees safety and quality level (Rj, v_0)



Dynamics of rise of expenses on safety and quality guarantee in US manufacturing companies in 1955-1990

Figure 5. General scheme of analysis

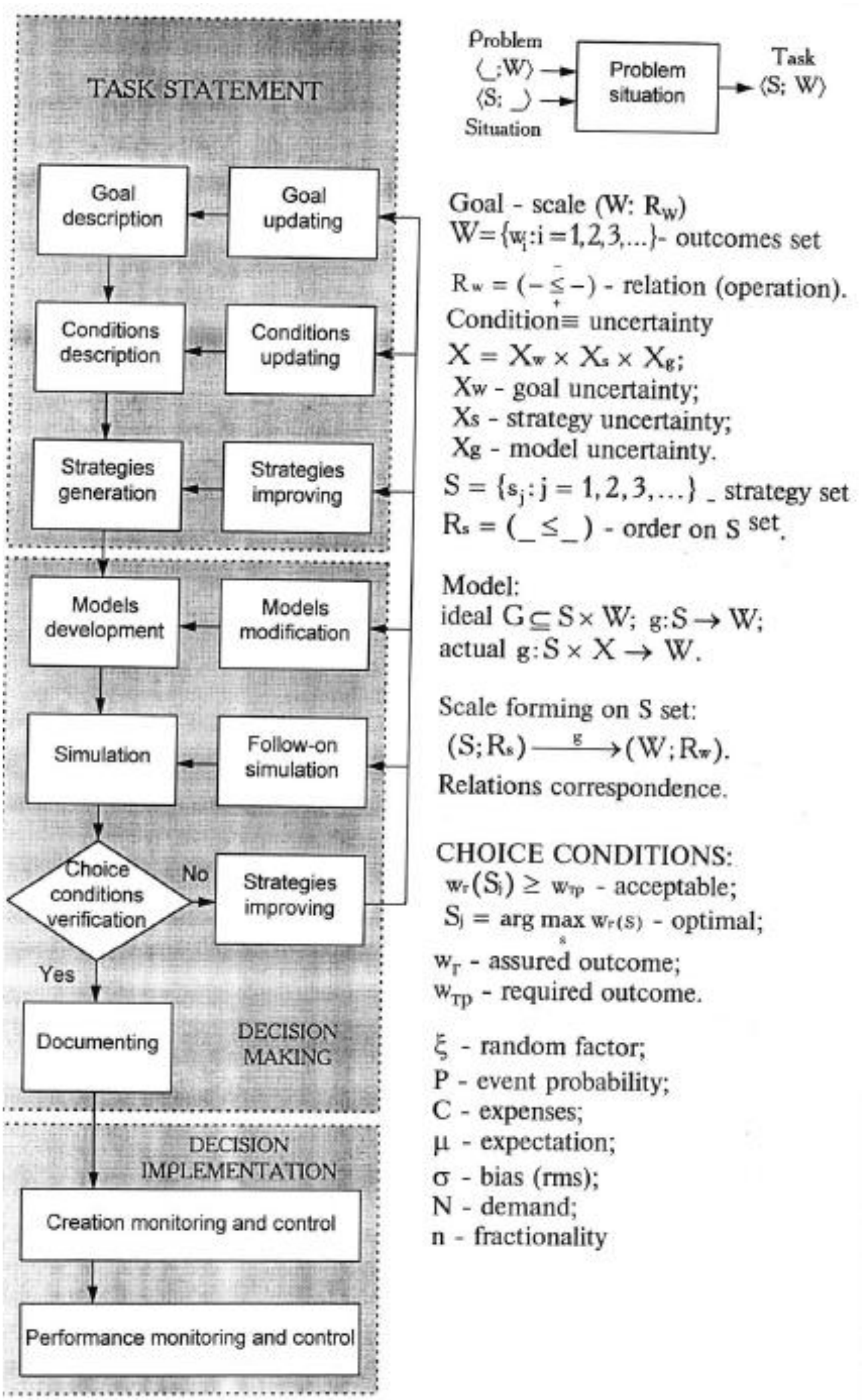
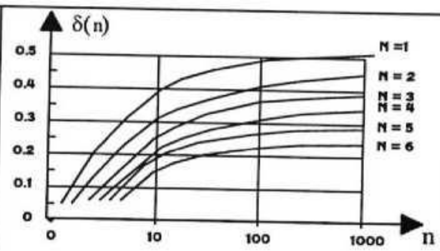
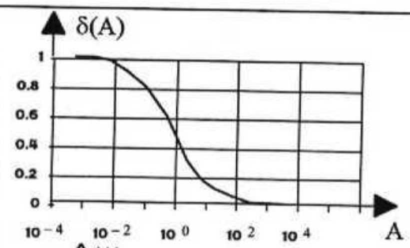
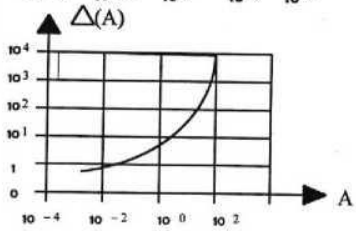


Figure 6. Principles of decision justification

1.PRINCIPLE OF A GARANTEED RESULT		
GARANTEE	ABSOLUTE	$w_{AГ} = \inf_{x} g(s,x) \quad (\forall x \in X)$
	PRACTICAL (β-level)	$w_{ПГ} = \inf_{x} g(s,x) \quad (\forall x \in [\underline{x}(\xi), \overline{x}(\xi)])$, where $[\underline{x}(\xi), \overline{x}(\xi)]$ - β-confidential interval

2. PRINCIPLE OF STOCHASTIC DETERMINISME			
FRACTIONAL	For $\rho_i = \rho_j^{1/n}$ $C_i = \frac{1}{n} C_j$ random event n- fraction	$\beta = \sum_{m=N}^{N_\Gamma} \binom{N_\Gamma}{m} \rho_i^m (1-\rho_i)^{N_\Gamma - m}$ $C_\Sigma = N_\Gamma \cdot C$ $\delta = \frac{C_\Sigma - C_{дp.\Sigma}}{C_\Sigma}$.	
STRATEGIES	For $m_i = \frac{1}{m} m_j$ $C_i = \frac{1}{n} C_j$ random values $\frac{\sigma_i}{m_i} = \frac{\sigma_j}{m_j}$ n-fraction	$N_\Gamma - t_\beta \cdot \frac{\sigma_i}{m_i} \sqrt{N_\Gamma} - N = 0$ $A = \frac{m^2 \cdot N}{t_\beta^2 \cdot \sigma^2}$ $\delta(A,\infty) = \frac{1+\sqrt{1+4A}}{2A+1+\sqrt{1+4A}}$; $\Delta(A) = \frac{C_\Sigma - C}{C} = \frac{1}{2}(A + \sqrt{A} \cdot \sqrt{A+4})$;	

3. PRINCIPLE OF CONSECUTIVE REMOVEL OF THE INCERTAINTY			
FLEXIBLE STRATEGIES	for two-alternative decisions $d(x): X_n \to D$; $D = D_1 \cup D_2$; $\dim X_n = n$; $P\{\theta_1\}; P\{\theta_2\}$; $P_{ij}, C_{ij}, i,j = 1,2$; $M[C] = \sum_{i,j} C_{ij} P_{ij}$.	Model: $M[C] = M[C_0] + P\{\theta_1\} \cdot (C_{12} - C_{21}) \times [1 - \int_{x_n^{(1)}} f(x/\theta_2) \exp\{I(\theta_1 \to \theta_2; x) - h\} dx]$ where: $M[C_0] = P\{\theta_1\} \cdot C_{11} + P\{\theta_2\} \cdot C_{22}$ $I(\theta_1 \to \theta_2; x) = \ln\left(\frac{f(x/\theta_1)}{f(x/\theta_2)}\right)$ $h = \ln\left[\frac{P\{\theta_1\} \cdot (C_{21} - C_{22})}{P\{\theta_2\} \cdot (C_{12} - C_{11})}\right]$ $\eta = M[C_0]/M[C]$	 losses without errors; measure of differentiating; discriminator; information efficiency.