Requirements Models:

- The Why-What-How model
- The 4-Variable model
- The Reference model
- The Goal-Service-Constraint model
- The 4-World model

What is RE?

What are requirements?

"... Requirements definition is a careful assessment of the needs that a system is to fulfill.

It must say why a system is needed,

based on current and and foreseen conditions,
which may be internal operations or an external market

It must say what system features will serve and satisfy this context.

And it must say how the system is to be constructed ..." *[Ross77]*

Not about the design

What is RE?

What are requirements?

why?

- **Enterprise requirements**

  for "context analysis" - the reasons why the system is to be created.
  (e..g, why IS for BPR, organizational structure, agents, goals)

  constraints on the environment in which the system is to function
  (e..g, airplane running beyond runway, AT&T Internet service)

  the meaning of system requirements
  (symbols, relationships, ontology, vocabulary)

what?

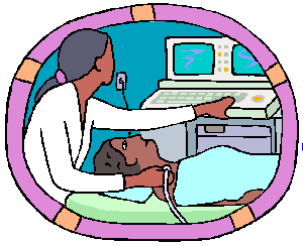
- **(System) functional requirements**

  a description of what the system is to do;
  what information needs to be maintained?
  what needs to be processes?
  {f: I -> O}

how?

- **(System) non-functional requirements**

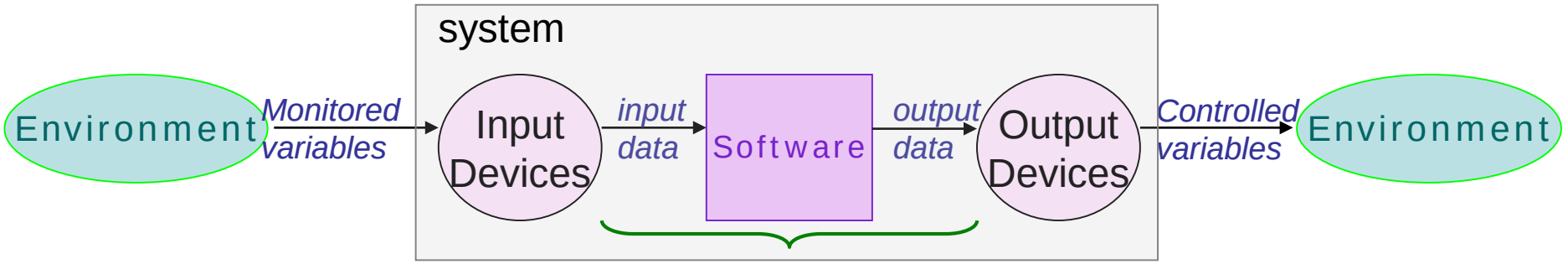
  (global) constraints on how the system is to be constructed and function.
  E.g., -ilities and -ities
  {bcfh(f: I -> O)}



The 4-Variable Model

(the functional documentation model)

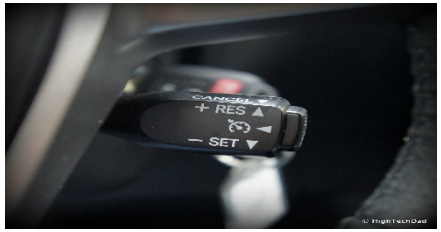
D.L. Parnas and J. Madey, "Functional Documentation for Computer Systems," Science of Computer Programming, Vol. 25, No. 1, Oct. 1995, pp. 41–61.

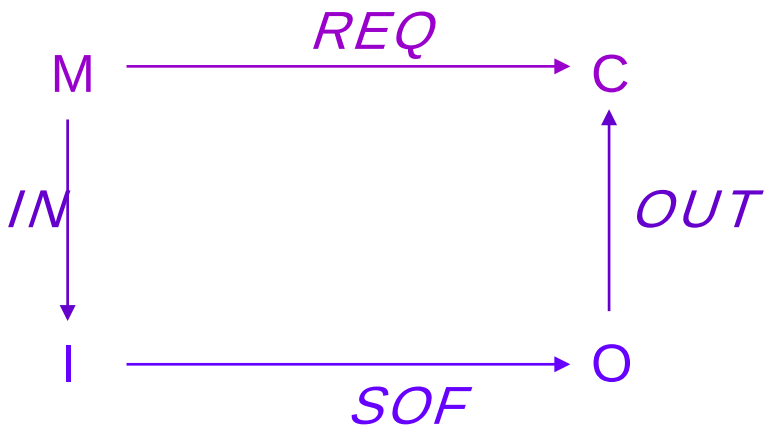


S - Specification of software in terms of inputs & outputs

(possibly large in number, and in very complex relationships)

Consider a cruise control system….



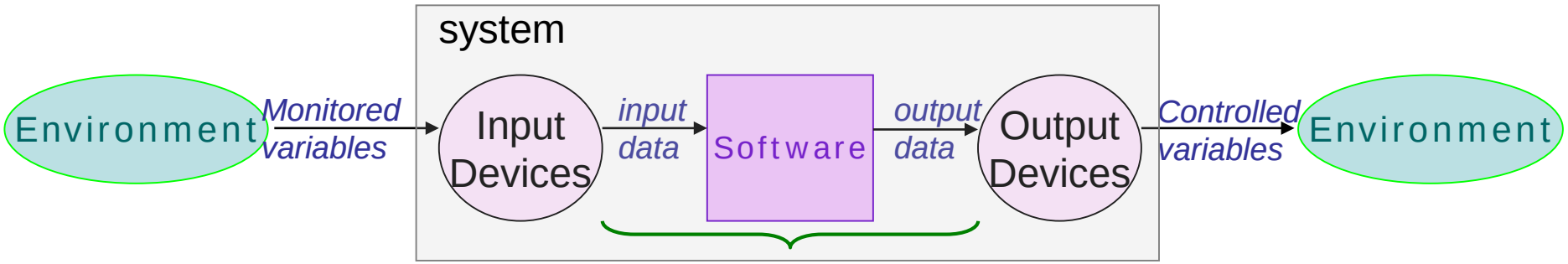

REQ
M
C
IN
OUT
I
O
SOF

The 4-Variable Model

(the functional documentation model)

D.L. Parnas and J. Madey, "Functional Documentation for Computer Systems," Science of Computer Programming, Vol. 25, No. 1, Oct. 1995, pp. 41–61.

a-fib.com



S - Specification of software in terms of inputs & outputs

(possibly large in number, and in very complex relationships)

NAT(m, c): describes nature without making any assumptions about the system;

REQ(m, c): describes the desired system behavior;

IN(m, i): relates the monitored real-world values to their corresponding internal representation;

OUT(o, c): relates the software-generated outputs to external system-controlled values; and

SOF(i, o): relates program inputs to program outputs.

Any issues?

Nat - the range of sounds detected or non-detected by the sensor and the possible range of values of the actuator controlling the buzzer.

Req - A warning that notifies the nurse if the system detects heart stops beating. The document' formalization: if the sound being monitored falls below a certain threshold, then the system sound the buzzer.

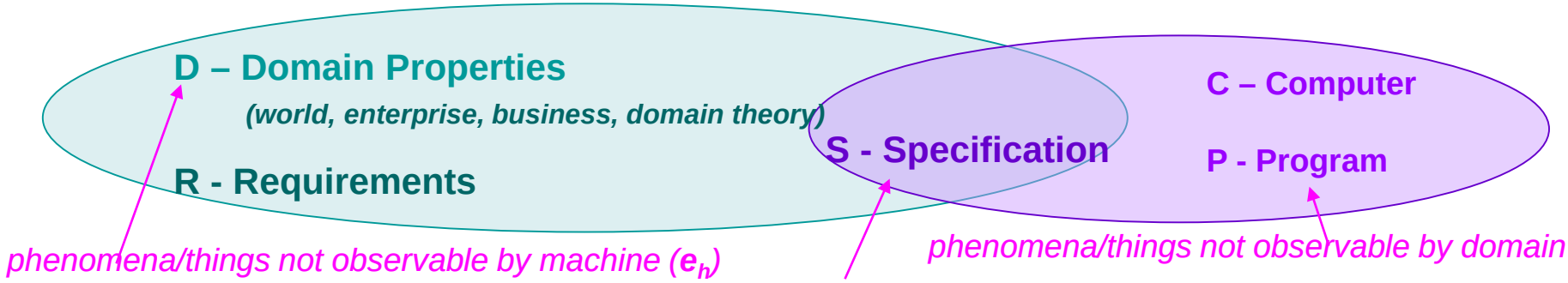
In - The input registers holding the data read from the sensor monitoring the sounds of the heart beat.
Out - The output registers which are read by the actuator that can sound the buzzer.

SOF - If the input register doesn't show signs of a heart beat for more than some specified time then the output register indicates the alarm to ring.

What are requirements?

[P. Zave and M. Jackson, Four Dark Corners of Requirements Engineering. *ACM Transactions on Software Engineering and Methodology* 6(1) 1-30. ACM Press. 1997]
[C. Gunter, E. Gunter, M. Jackson and P. Zave, "A Reference Model for Requirements and Specifications," IEEE Software, May/June 2000. pp. 37-43]

The WRSPM Model = The Reference Model



$e = e_h \cup e_v$ $\quad e_h \cap e_v = \Phi$ $\quad e \cap s = \Phi$ $\quad s = s_v \cup s_h$ $\quad s_v \cap s_h = \Phi$

- **Domain Properties:** **(indicative, = assumptions=domain knowledge)**
  things in the environment (application domain) that are true regardless of the proposed system
- **Requirements:** **(optative)**
  things in the application domain that we wish to be made true through the proposed system
  "Many phenomena not accessible by the machine"
- **Specification:**
  a description of the behaviors that the program must have in order to meet the requirements
  "Can, and should, only be written in terms of shared phenomena"

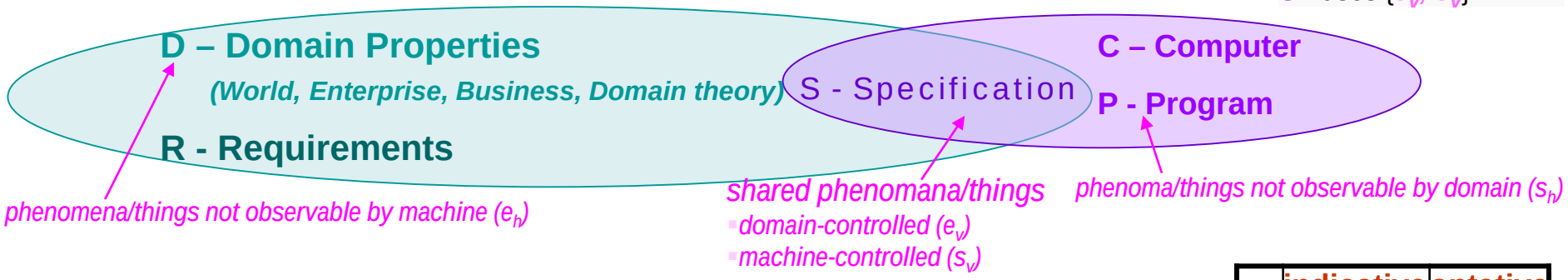
❖ *Designated Terminology* – names/vocabulary to describe W, (R), S, M in terms of phenoma – typically states or events

Requirements should contain *nothing but* information about the *environment*.

[P. Zave and M. Jackson, Four Dark Corners of Requirements Engineering. *ACM Transactions on Software Engineering and Methodology* 6(1) 1-30. ACM Press. 1997]

The WRSPM Model

W, R - uses {e_h, e_v, s_v}
P, M - uses {e_v, s_v, s_h}
S - uses {e_v, s_v}



	indicative	optative
e_h	✓	✓
e_v	✓	✓
s_v	✓	✓

- Requirements describe what is observable at the interface between the environment and the machine – hence exist only in the environment;
- Anything else is regarded as implementation bias;
- States in Specifications should describe states of the environment – *hence, specification languages intended to describe internal (program) states of the machine are inadequate.*

Verification: S, D ⊨ R

P, C |= S

Consequences

- Freedom to collect and record information about the environment even before we are sure it will be needed ***(i.e., no minimality restriction - there must be nothing that is not necessary to carry out the currently proposed machine functions.);***
- Designations refer to the real world, and machine states may have NO direct correspondence to it

What are requirements?

Example 6: Coffee Machine

D1: Before the switch is moved to the On position, the user must add ground coffee to the filter and insert it in the coffee machine.

D2: Before the switch is moved to the On position, the user must add water to the reservoir.

R1: When the user moves the three-way switch to the On position, coffee shall be brewed.

S1: If the three-way switch is On, the coffee brewer shall be actuated

C – with a switch as a sensor and a brewer as an actuator

P - Program

Designation Categories:

e_h: ?

e_v: ?

s_v: ?

s_h: ?

Are the D's complete?

What are requirements?

[C. Gunter, E. Gunter, M. Jackson and P. Zave, "A Reference Model for Requirements and Specifications," IEEE Software, May/June 2000. pp. 37-43]

Example 1: Patient Monitoring

D1: There will always be a nurse close enough to hear the buzzer

D2: The sound from the heart falling below a certain threshold indicates that heart has (is about to) stop

R1: A warning system notifies the nurse if the patient's heartbeat stops

C – with a microphone as a sensor and a buzzer as an actuator

S1: If the sound from the sensor falls below a certain threshold, the buzzer shall be actuated

P - Program

Designation Categories:

e_h: the nurse and the heartbeat of the patient.

e_v: sounds from the patient's chest.

s_v: the buzzer at the nurse's station.

s_h: internal representation of data from the sensor.

What if the domain assumptions are wrong?

What are requirements?

[C. Gunter, E. Gunter, M. Jackson and P. Zave, "A Reference Model for Requirements and Specifications," IEEE Software, May/June 2000. pp. 37-43]

Example 1: Patient Monitoring

D1: There will always be a nurse close enough to hear the buzzer

D2: The sound from the heart falling below a certain threshold indicates that heart has (is about to) stop

R1: A warning system notifies the nurse if the patient's heartbeat stops

S1: If the sound from the sensor falls below a certain threshold, the buzzer shall be actuated

C – with a microphone as a sensor and a buzzer as an actuator

P - Program

What?

$S, D \models R$

$P, C \models S$

Relationship between the 4-variables and the event types here?

What is RE?

"... Requirements Engineering is the branch of Systems engineering concerned with

real-world goals for,
services provided by, and
constraints on

software systems

Requirements engineering is also concerned with

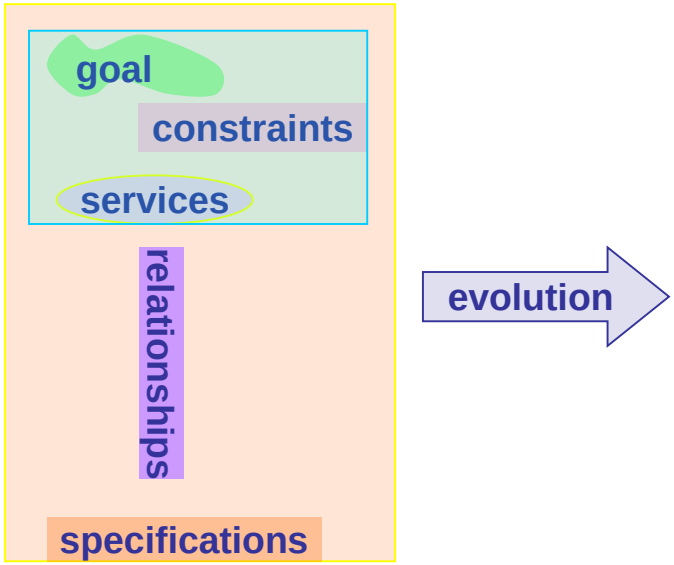
the relationships of these factors

to precise specifications of system behavior

and

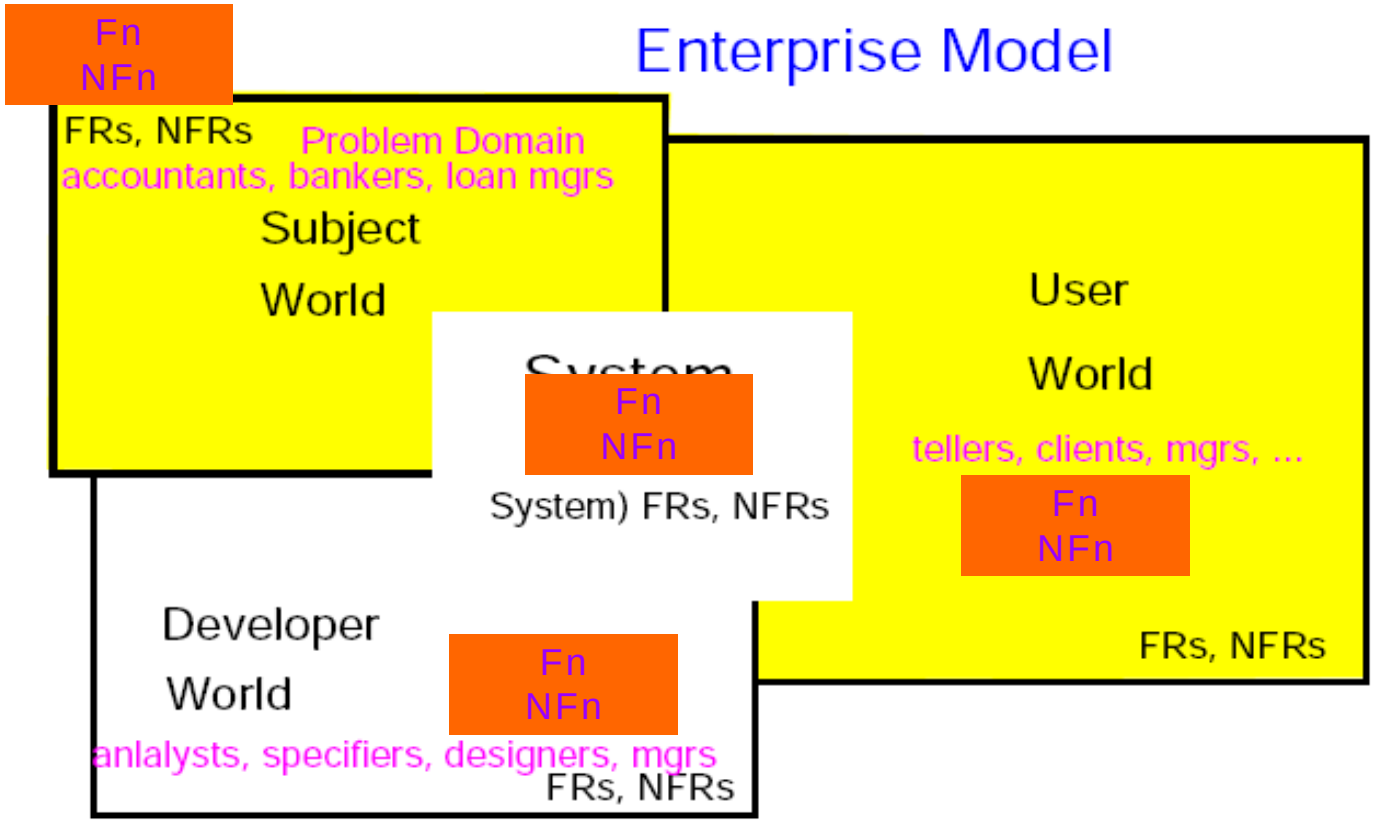
to their evolution over time and across system families..."

[Zave94]



What to elicit?

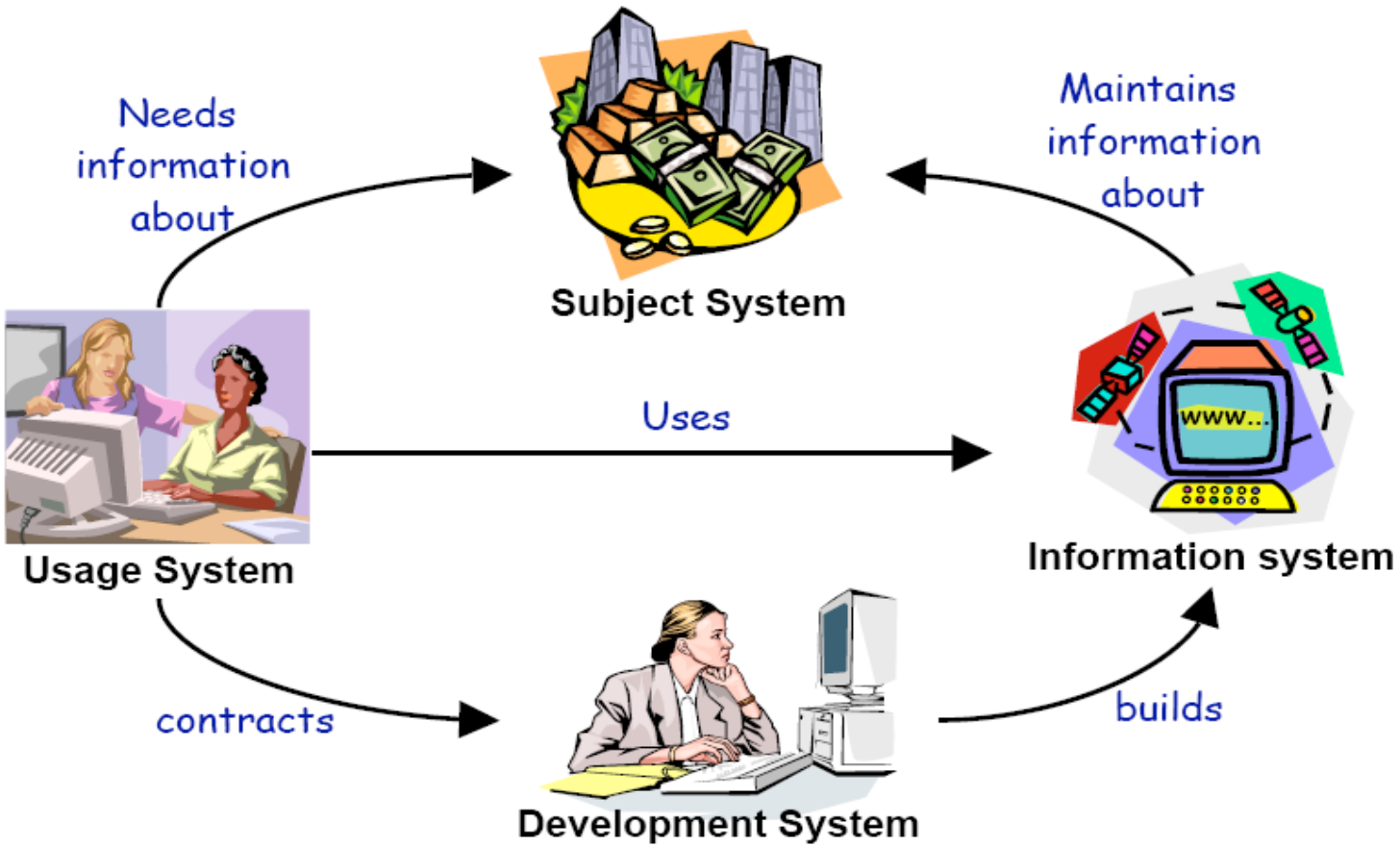
Four Worlds of RE



What is unique in this model?

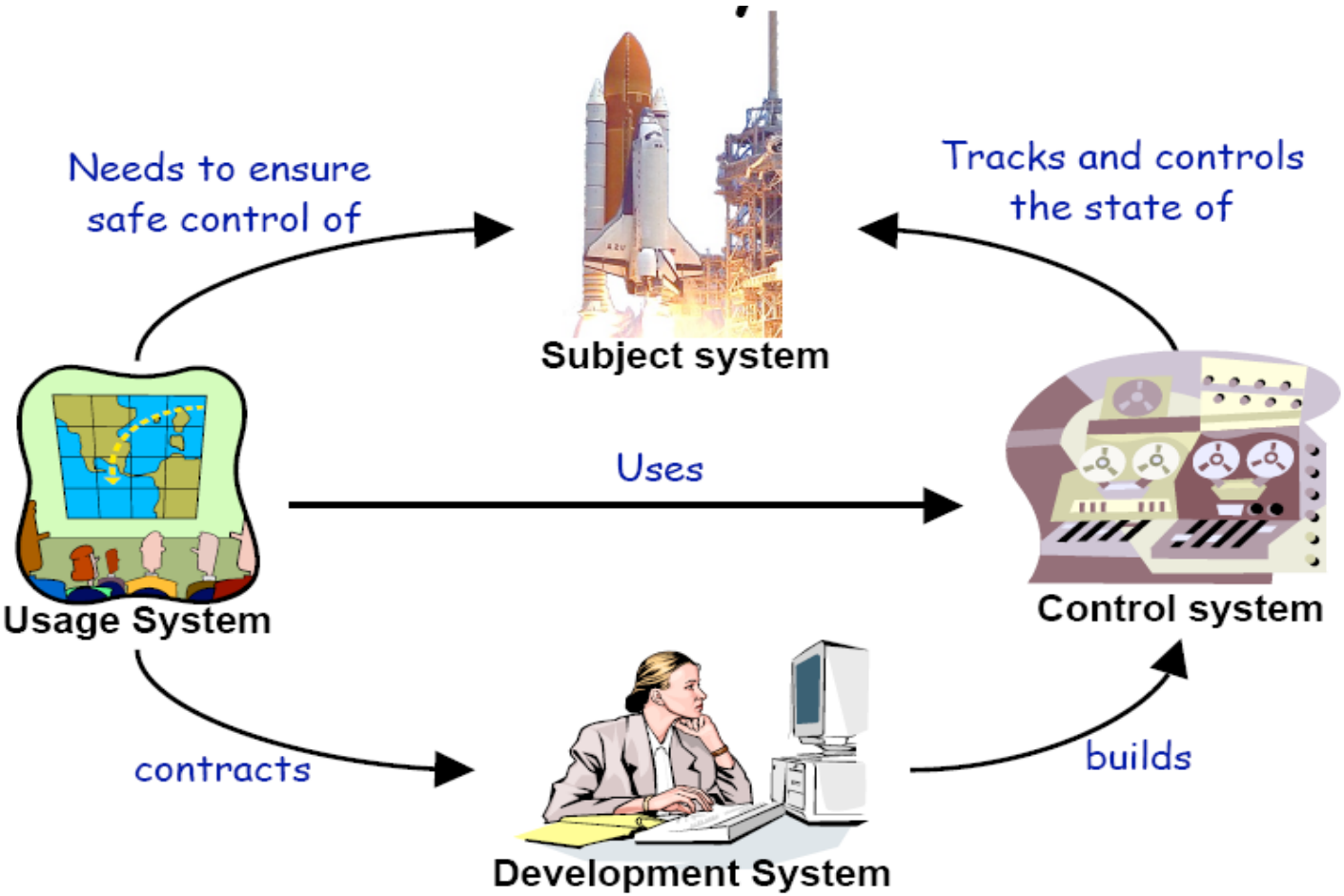
Four Worlds of RE for Information Systems

Adapted from [LK1995, p73] [S. Easterbrook, 2000-20



How does this relate to RE process?

Four Worlds of RE for Control Systems



Recall: Models about Requirements Revisited

The Why-What-How Model

The WRSPM M

Requirements should contain *nothing but* information about the environment.

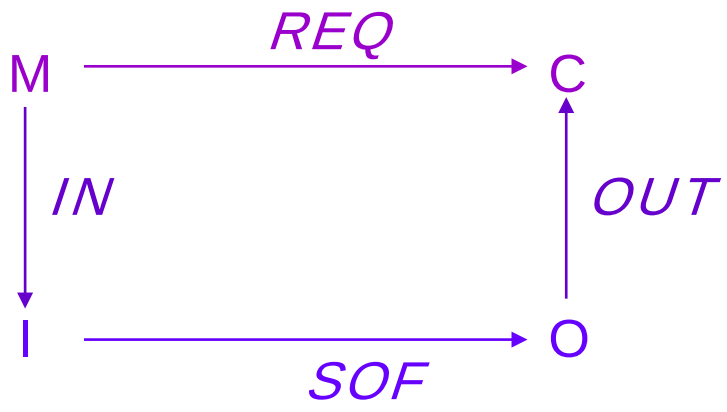
W, R - uses {e_h, e_v, s_v}
P, M - uses {e_v, s_v, s_{hv}} S - uses {e_v, s_v}

D – Domain Properties
(World, Enterprise, Business, Domain theory)
R - Requirements

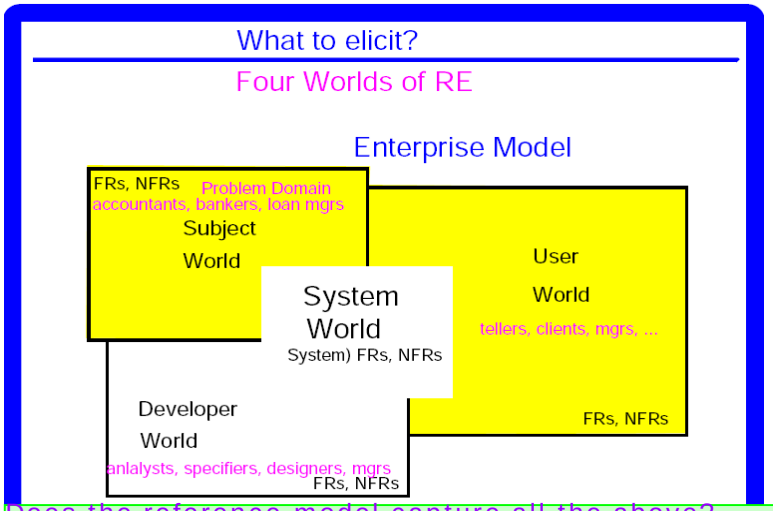
S - Specification

C – Computer
P - Program

- *The 4-variable model:*



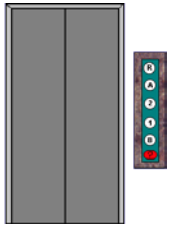
- *The goal-service-constraint model:*



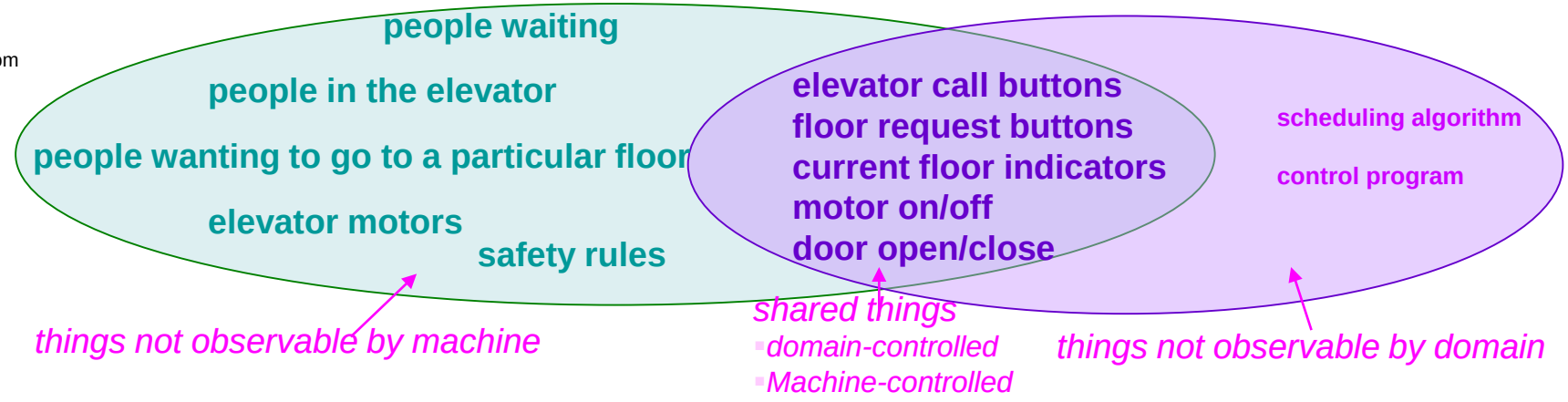
Does the reference model capture all the above?
Where are goals, services and constraints? [Zave94]
Which is about S, D |= R?
Which is about technical feasibility, component reuse, etc.?
Where is traceability?

Boundaries are not fixed

Example 1: Elevator control system



www.geocities.com



E.g. Add some sensors to detect when people are waiting
This changes the nature of the problem to be solved

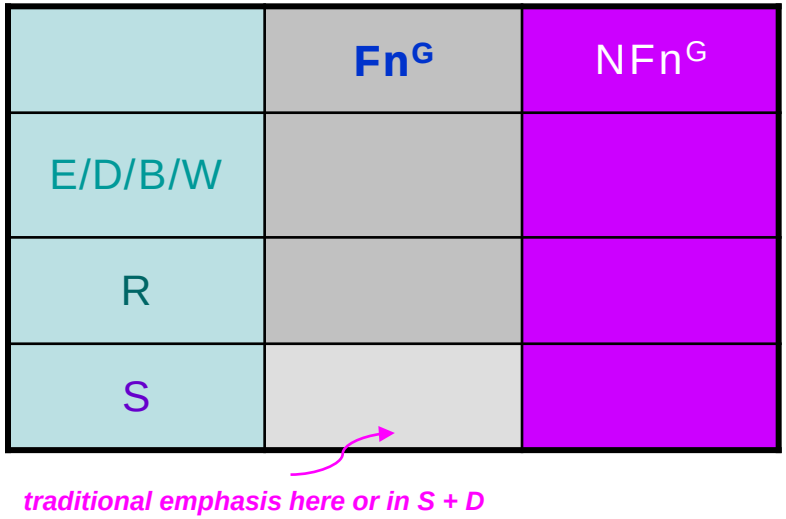
An Integrated Model

-**Ross:**

- **why (context – Environment/Enterprise, Domain, Business, World)**
- **what (Fn)**
- **how (NFn)**

- **Reference model: W/D. R. S**

- **Zave: Goal**

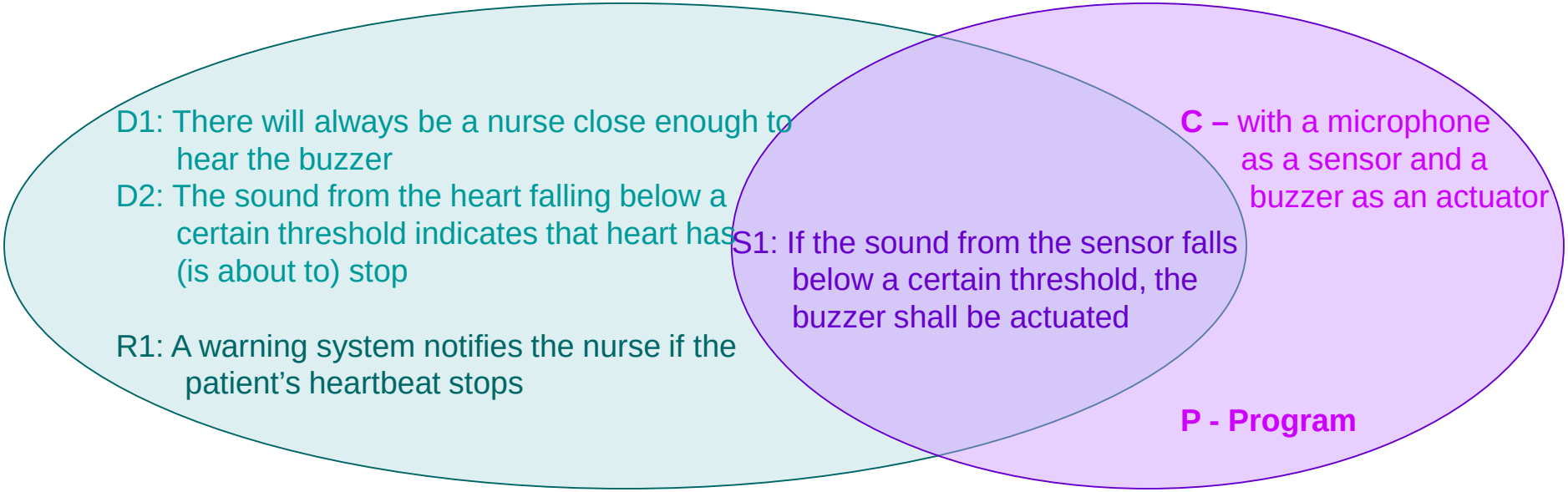


More models & Goal-orientation – these later in Elicitation & Modeling)

Some Questions

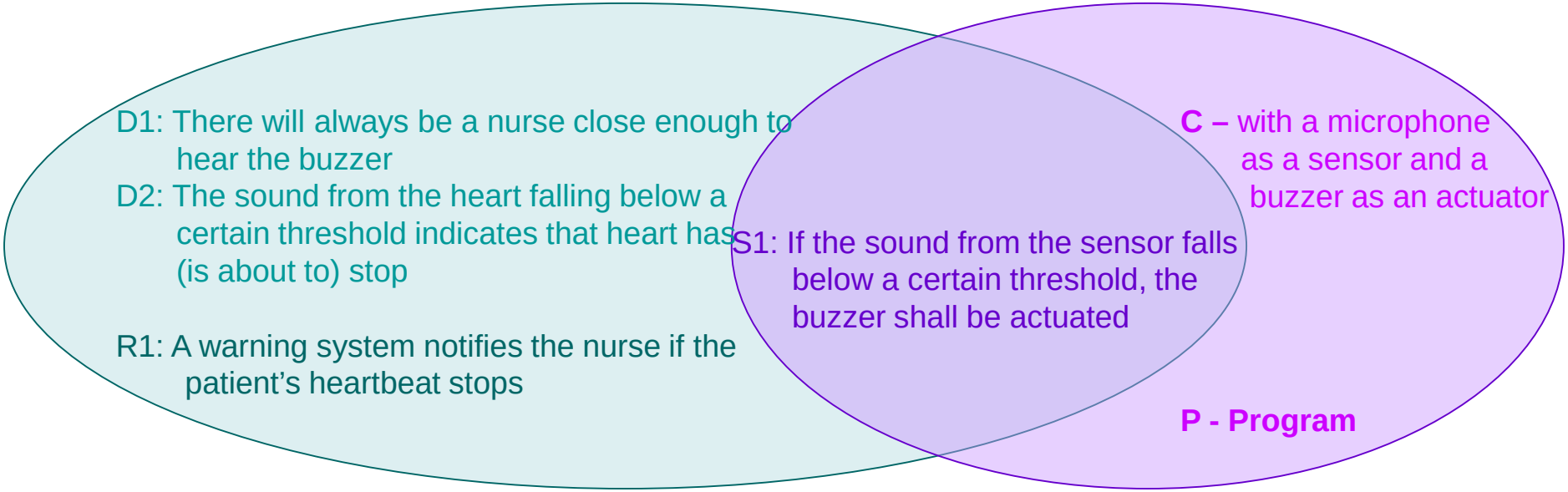
Revisiting the Reference Model

Any issues with this requirement?



Revisiting the Reference Model

Any issues with this requirement?

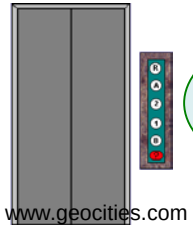


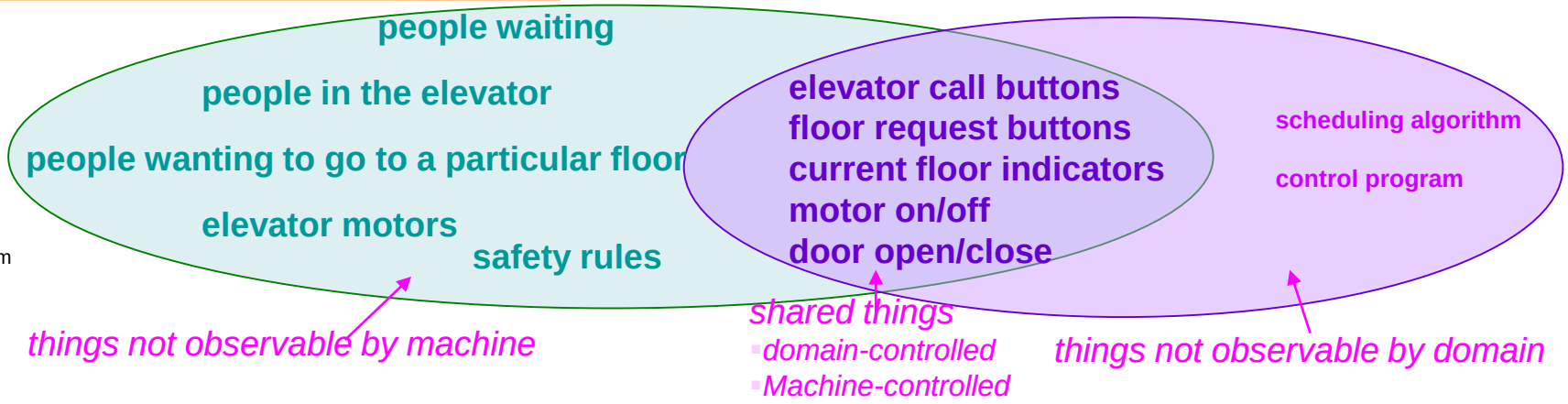
What if a warning system notifies the nurse one year after the patient's heartbeat stops?

Is this warning system really what we want?

Boundaries are not fixed

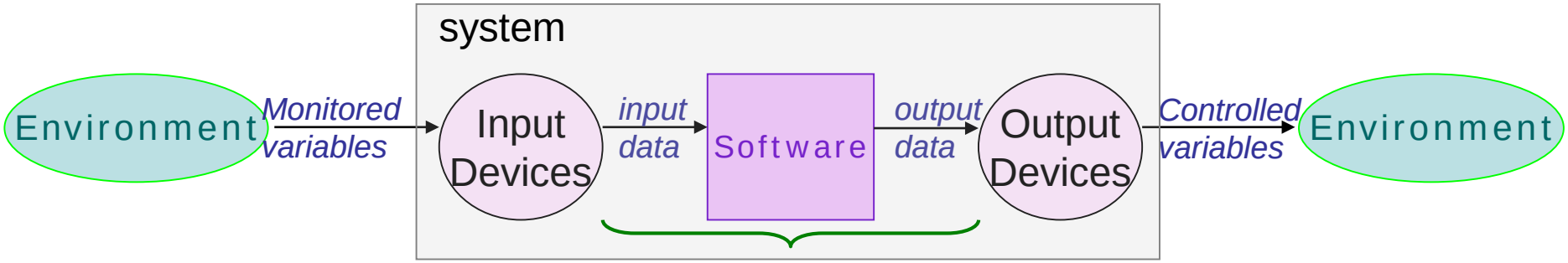
Example 1: Elevator control system





E.g. Add some sensors to detect when people are waiting
This changes the nature of the problem to be solved

Example 2: The 4-variable model



S - Specification of software in terms of inputs & outputs
(possibly large in number, and in very complex relationships)

Systems engineer decides - what application domain phenomena are shared
- the boundaries by designing the input/output devices
- I/O data as proxies for the monitored and controlled variables

Boundaries are not fixed

- Consider coffee brewing machine

- Consider patient monitoring system


¡MUCHAS
GRACIAS!

Appendix

What are requirements?

www.sergolf.com

Example 2: Traffic lights

D1: Drivers stop at red lights
D2: Pedestrians walk when green

R1: Allow pedestrians to cross the road safely

S1: Show a red light to the cars and a green light to the pedestrians

C – Computer

P - Program

Example 3: Traffic Lights - Safety

D1. Drivers stop at red lights
D2. Pedestrians stop at red lights
D3. Drivers drive at green lights
D4. Pedestrians walk when green

R1: Pedestrians and cars cannot be in the intersection at the same time

S1: Never show a green light to both pedestrians and cars

C – Computer

P - Program

What if the domain assumptions are wrong?

What are requirements?

Example 4: Aircraft Control

D1: Wheel pulses on if and only if wheels turning
D2: Wheels turning if and only if moving on runway

R1: Reverse thrust shall only be enabled when the aircraft is moving on the runway

S1: Reverse thrust enabled if and only if wheel pulses on

C – Computer

P - Program

Example 5: Security

D1: Authorized personnel have passwords
D2: Passwords are never shared with non-authorized personnel

R1: The database shall only be accessible by authorized personnel

S1: Access to the database shall only be granted after the user types an authorized password

C – Computer

P - Program

What if the domain assumptions are wrong?

What Are Requirements?

Example 7: In a single-customer banking environment,

- Notation: equational logic
- *action(a):* atomic and sequential;
- *earlier(a1, a2):* a nondense total order on actions;
- *pause(p):* a unique pause between each adjacent pair of actions
- *begins(a,p):* action *a* precedes pause *p* immediately in the temporal sequence
- *ends(a,p):* action *a* succeeds pause *p* immediately in the temporal sequence
- *(*i | R(i) : P(i)):* the accumulation of values *P*(*i*), using operator *, over all values *i* for which predicate *R*(*i*) holds.

D

- *deposit(a,m):* *a* is an action in which amount *m* is deposited
- *withdrawal-request(a,m):* *a* is an action in which a withdrawal of amount *m* is requested
- *withdrawal-payout(a,m):* *a* is an action in which amount *m* is paid out as a withdrawal
- *balance(b,p):* during pause *p* the balance is amount *b;*

At any time, the balance is equal to the sum of the amounts of all the previous deposits, minus the sum of the amounts of all the previous withdrawal payouts:

$$(\forall\ b,p \mid : balance(b,p) \equiv$$
$$(b = (+m \mid (\exists a \mid : deposit(a,m) \wedge earlier(a,p)) : m) - (+m \mid (\exists a \mid : withdrawal\text{-}payout(a,m) \wedge earlier(a,p)) : m)))$$

R

A withdrawal request leads to a withdrawal payout, if the requested amount is less then the current balance

$$(\forall\ a,m,p,b \mid withdrawal\text{-}request(a,m) \wedge ends(a,p) \wedge balance(b,p) \wedge b \geq m:$$
$$(\exists a' \mid : withdrawal\text{-}payout(a',m) \wedge earlier(a,a')))$$

S – a requirement (**R**), which is implementable, hence a specification

$$(\forall\ a,m,p \mid withdrawal\text{-}request(a,m) \wedge ends(a,p) \wedge m \leq$$
$$((+m \mid (\exists a \mid : deposit(a,m) \wedge earlier(a,p)) : m) - (+m \mid (\exists a \mid : withdrawal\text{-}payout(a,m) \wedge earlier(a,p)) : m)) :$$
$$(\exists a' \mid : withdrawal\text{-}payout(a',m) \wedge earlier(a,a')))$$

What is RE?

What are requirements?

"... Requirements definition is a careful assessment of the needs that a system is to fulfill.

It must say **why** a system is needed,

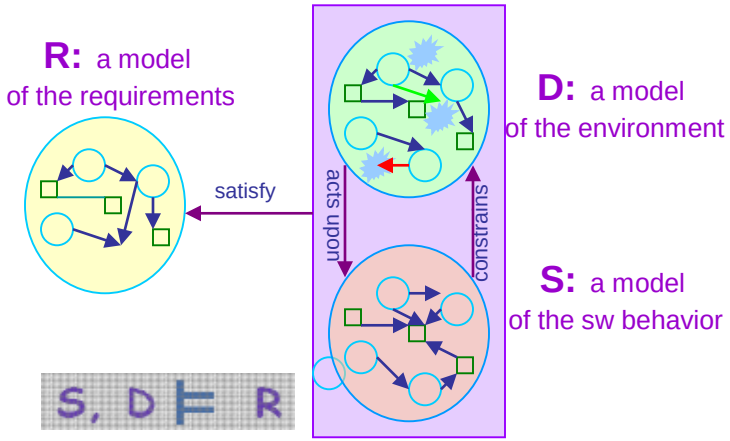
based on current and and foreseen conditions,
which may be internal operations or an external market

It must say **what** system features will serve and satisfy this context.

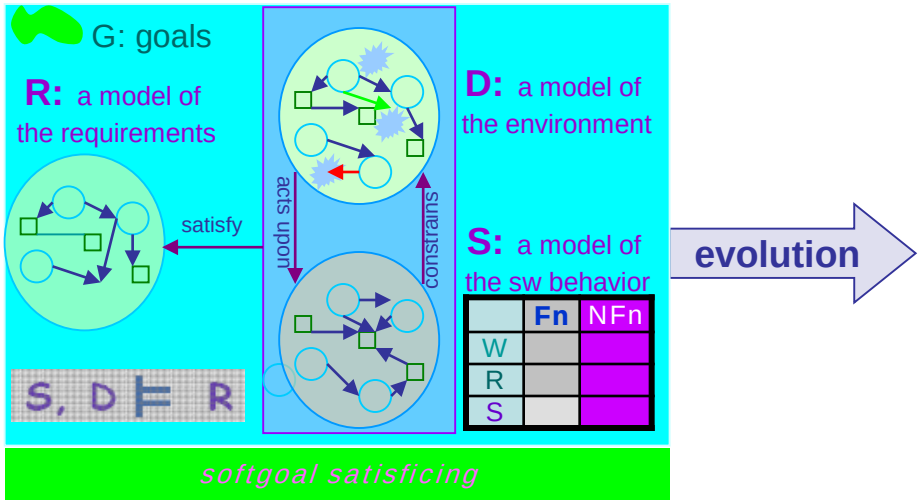
And it must say **how** the system is to be constructed ..."

[Ross77]

	Fn	NFn
E/D/B/W		
R		
S		



$M^G, Prog^G \models S^G;\ S^G, D^G \models R^G;\ R^G, D^G \models G;\ (G \models \neg P)\ V\ (G \models\sim \neg P)$



$M^G, Prog^G \models S^G; S^G, D^G \models R^G; R^G, D^G \models G; (G \models \neg P) \vee (G \mid\sim \neg P)$