São Paulo 2025

IAA AAI SECTIONS

IBA
Instituto Brasileiro de Atuária

Embedding Prevention in Sustainable Insurance Solutions

A dynamic and integrated view on solvency and systemic risk

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AGEAS/ ACTUARIAL FUNCTION OFFICER REINSURANCE

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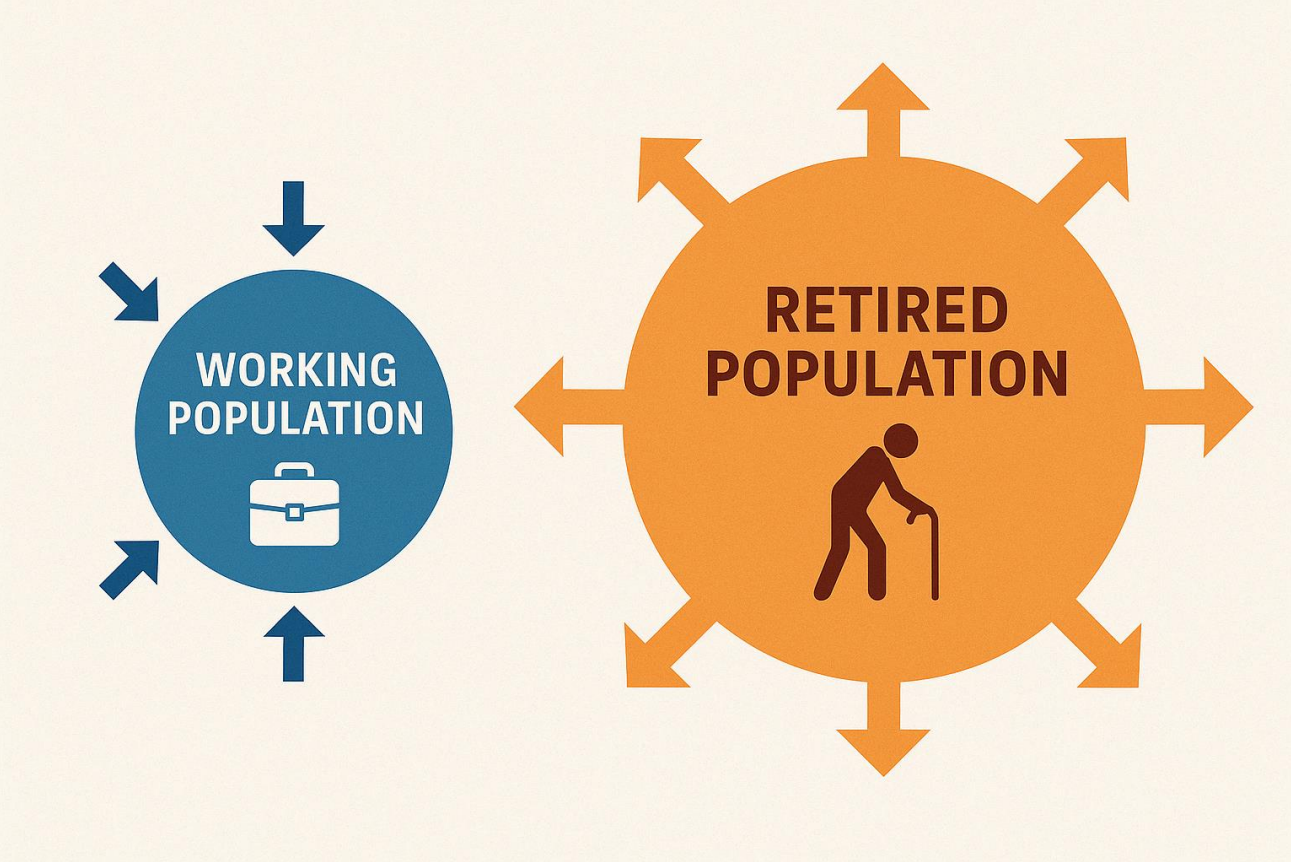
HEALTH & SOLVENCY IN AN AGING WORLD

Health & Solvency Systems in an aging demographic

Ageing Population: A Global Health Pressure Point



Rising pressure on pension systems
Defined contribution plans face sustainability challenges

Retirement ages are increasing
Workers expected to stay active longer and more productive

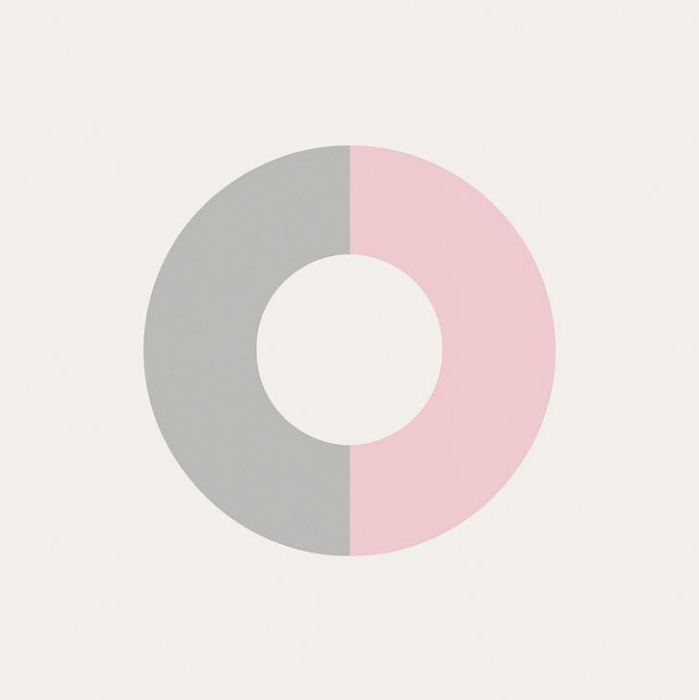
Healthcare costs are surging
Greater demand for chronic-care services

What ageing populations **need most: Good Health.** Human wellbeing is the true currency of longevity

Meaning of Solvency

Health Etymology

Old English – Whole, being whole



Understanding health
through cognitive framing

Establishes Mind-Body connection

Solvency Etymology

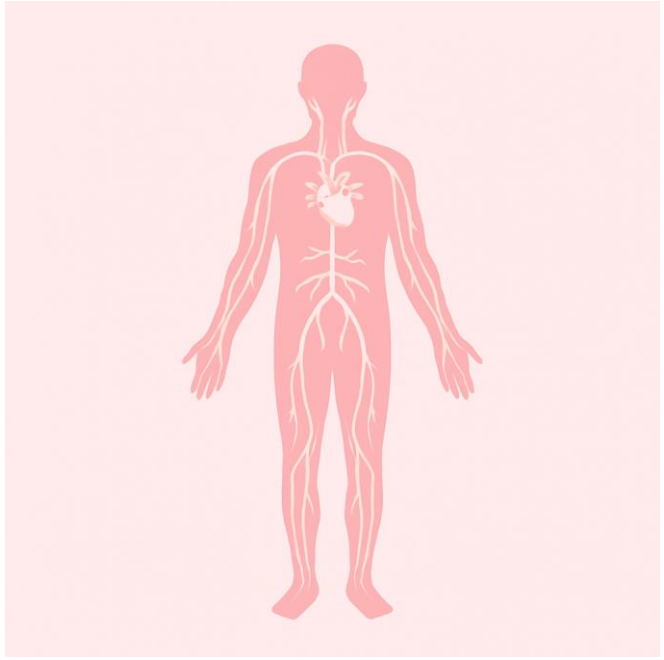
Latin – Solvere- To loosen , to breathe

Ensuring Capital Flows to the
right place at the right time

Promotes dynamic and flexible capital allocation capabilities

Health is Balance - Natural vs Actuarial Systems

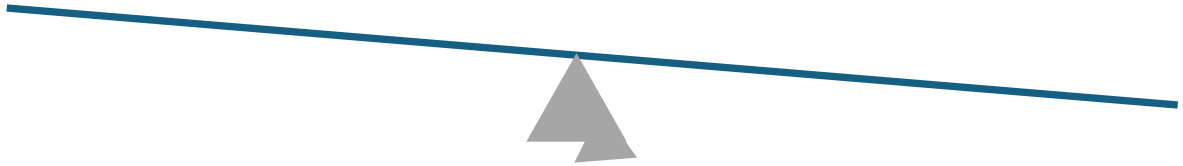
Natural Systems
Self – Regulate



Balance = Health
(Homeostasis)

Actuarial Systems
Follow Regulation

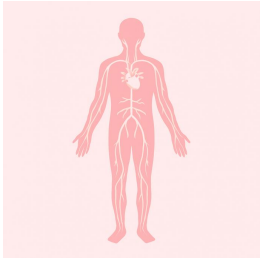
Balance = Financial Health (Solvency Capital)



Imbalance = System Stress
(Disease/Financial Crisis)

Balancing Systems are Dynamic

Natural Systems
Free Energy Principle-
A cognitive perspective



- Action and perception work in tandem to create feedback loops and **minimize predictive error**
- Stays within given bounds – Maintains system **integrity and structure**
- Non-Equilibrium steady state – **Dynamic**

Actuarial Systems
A regulatory stabilizing mechanism and risk assessment process

- **Reporting lags** in a three pillared solvency framework can **disrupt feedback loops**
- Data siloes expose **inconsistencies** and **computational inefficiencies**
- Risk scenarios and statistical models that shape solvency balance sheet and P&L accounts are **discrete and episodic**

Dynamic Solvency Intelligence (DSI)* aims to mirror the intelligence of natural intelligence to minimize predictive error through data exploitation and risk exploration whilst preserving system integrity and transparency

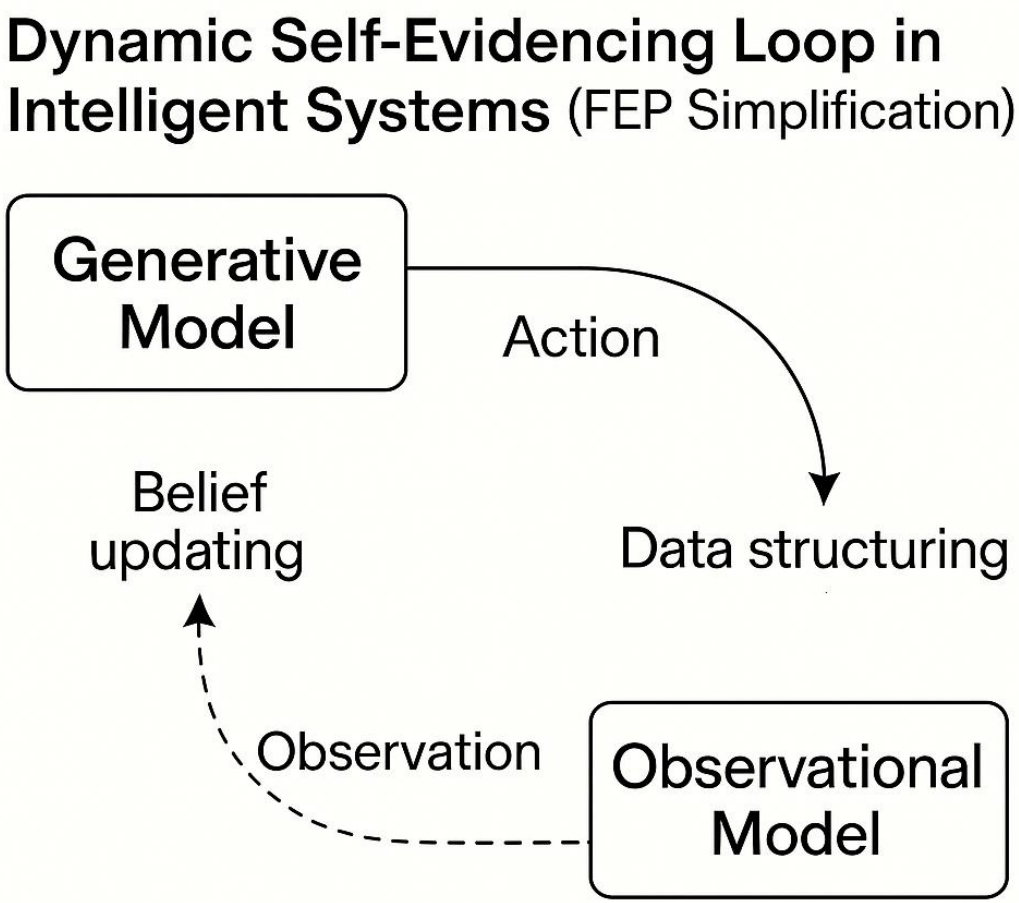
** See appendix*

NATURAL INTELLIGENCE & SYSTEM DYNAMICS

Relating natural intelligence to solvency through the Free Energy Principle

How Dynamic Systems Stay Healthy

Learning through feedback loops – Balancing Belief and Data

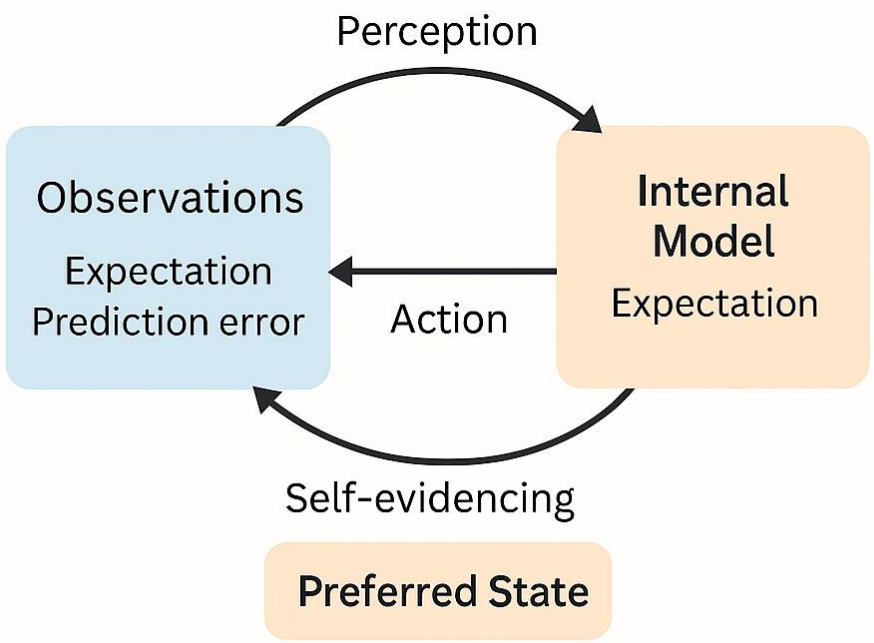


Follows a **Action-Perception loop**, this loop can also be framed as a control – belief loop

Continuously move from **model to data and data to model**

Involves not just frequent updates, but the simultaneous restructuring of both beliefs (model) and observations (data structure).

Adaptive Stability through Self- Evidencing and Surprise Minimization



A dynamic system minimizes surprise to remain in a stable attractor basin.

Maintaining stability of Dynamic Systems

Self evidencing provides stability

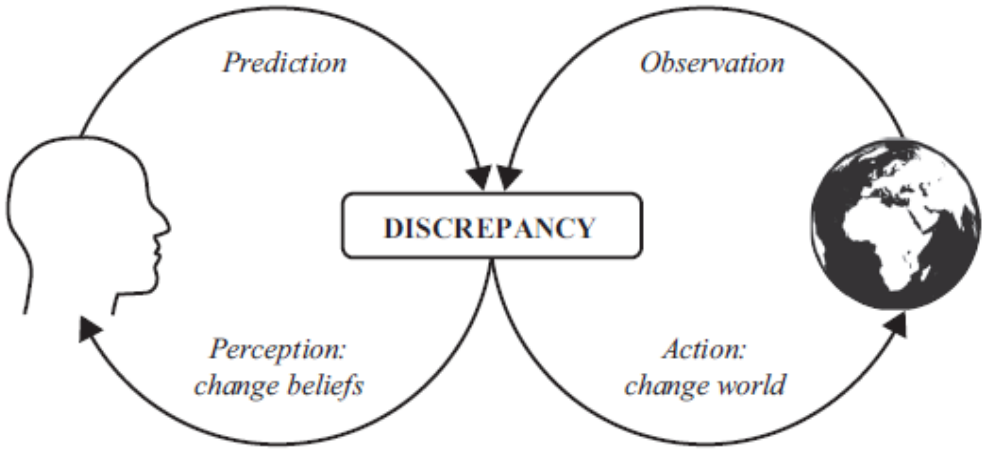
- If data fits the model, beliefs are strengthened
- If data contradicts the model, beliefs are updated
- Over time self evidencing enables convergence and maintenance to a steady, self – sustaianing balance with the environment

Goal of self evidencing is **Surprise Minimisation**

By minimizing surprise, we **preserve coherence** around preferred state and move towards attractor set

Bridging Alignment and Optimization

Agent with capacity of active inference



P26 The Free Energy Principle in Mind, Brain, and Behavior
Thomas Parr, Giovanni Pezzulo, and Karl J. Friston

Alignment, Optimization, and the Pivot of KL Divergence

KL Divergence measures the discrepancy between prediction and observation – a signal of misalignment

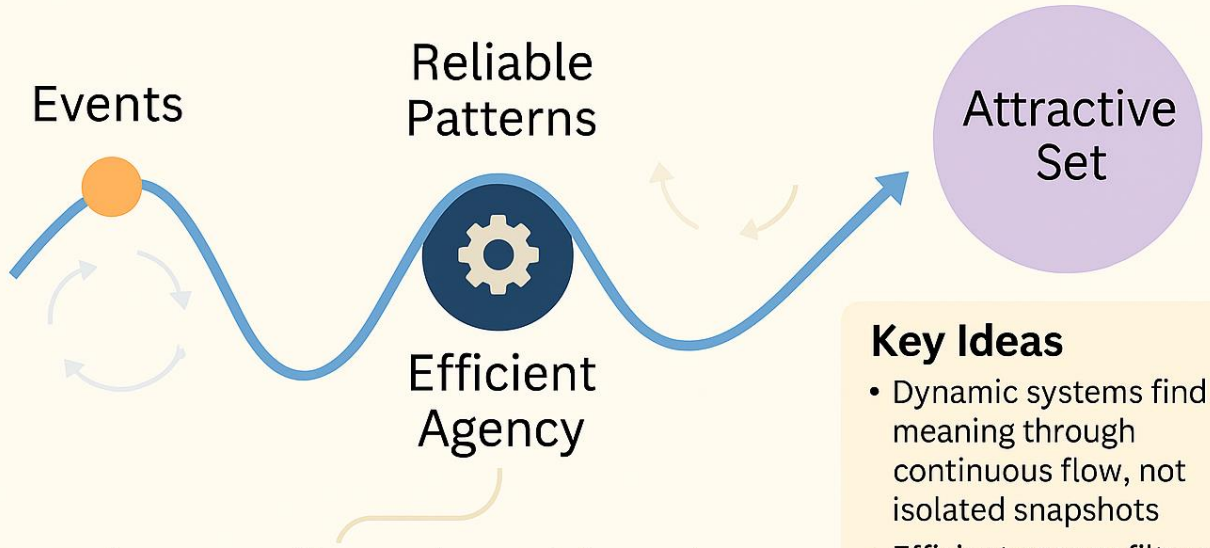
Through active inference, systems minimize this gap by updating beliefs or acting on the world

Optimization filters feedback to serve local goals – like profit and growth

But maximizing local activity can distort broader signals, leading to systemic misalignment

KL Divergence is the pivot – it reveals when local optimization begins to erode global alignment

Finding Meaning Through Flow and Attractors



Key Ideas

- Dynamic systems find meaning through continuous flow, not isolated snapshots
- Efficient agency filters relevant information (Markov Blanket) to guide adaptation

From Risk Signals to Systemic Stability

- Efficient agency filters relevant information (via the Markov Blanket) based on emerging patterns of value and risk.
- Events (point estimates) and patterns (distribution shapes) co-evolve: distributions guide expectations, events reshape distributions.
- Attractor sets stabilize meaning — the system gradually converges to preferred states in its environment, balancing prediction and adaptation.

Dynamic systems create meaning through continuous flow — continuously updating both spatial beliefs (probability distributions) and temporal beliefs (stochastic processes like time series).

IMPLEMENTATION & PARTNERSHIP FRAMEWORKS

Operational Architecture and Financial Innovation

Principle Vs Risk Vs Value Based Solvency Frameworks

Evolving Solvency Thinking

Are you following the rules? (static threshold)

Are you modeling risks? (probabilistic but reactive)

Are you aligning to what matters dynamically? (adaptive meaning)

A Solvency Framework where meaning, survival and dynamic flow guide adaptation and truly operationalize ESG and prevent « Greenwashing ».

Comparison: Traditional Vs Dynamic Stability Systems

Category	Aspect	Traditional Actuarial System (without FEP)	FEP-Based Dynamic System
Stability (Self-Evidencing) 	System Stability	Relies on periodic validation against realized experience.	Maintains stability through continuous self-evidencing — the system validates its beliefs constantly through incoming observations.
	Surprise Minimization	Deviations from assumptions are accepted and buffered with capital.	Stability is achieved by continuously minimizing surprise — small, ongoing belief adjustments preserve coherence and prevent large shocks.
	Attractor Behavior	Maintain targets via external constraints (e.g., solvency thresholds, capital buffers).	Evolve toward preferred stable states (attractors) dynamically, minimizing surprise and reinforcing internal consistency.
	Boundary (Markov Blanket)	Boundary defined mechanically (business units, solvency frameworks).	Boundary maintained dynamically through Markov blankets — selectively regulating exchanges with the environment to preserve internal coherence.
Adaptivity (Flow and Adjustment) 	Adjustment Approach	Recalibrate models periodically (e.g., year-end reserving, quarterly pricing updates).	Continuous belief updating through online flow monitoring — real-time adaptation to changing conditions.
	Risk Handling	Build static buffers and capital margins to absorb shocks.	Actively reshape behavior to anticipate, absorb, and neutralize surprises early.

Comparison: Decision – Making and Learning Frameworks

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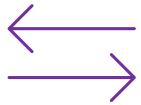
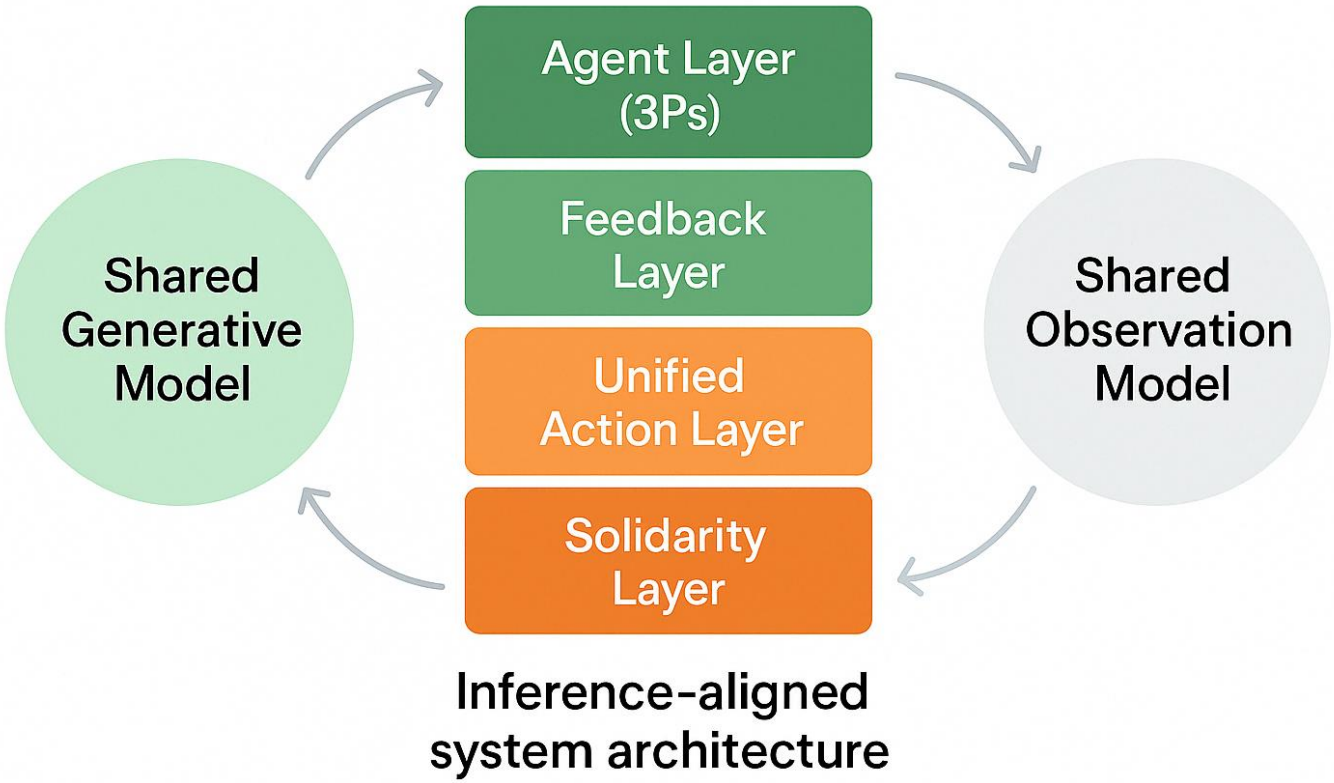
Category	Aspect	Traditional Actuarial System (without FEP)	FEP-Based Dynamic System
Agency (Decision-Making) 	Action Strategy	Decision-making triggered by predefined thresholds (e.g., rerate if LR > 70%).	Decision-making based on fluid patterns of emerging evidence — constant fine-tuning in light of new observations.
	Goal Framing (Alignment)	Operate toward fixed performance targets (e.g., maximize solvency ratio, minimize loss ratio).	Continuously align internal objectives with evolving external realities — ensuring actions remain meaningful and adaptive.
	Agency Expression	Agency reacts to deviations after they occur.	Agency actively steers the system toward preferred states through continuous self-regulation.
Learning through feedback 	Feedback and learning	Learning is periodic and batch –based (e.g, experience studies,quarterly reviews, annual model validations).	Learning is continuous and online, every new piece of data updates beliefs slightly; feedback is an essential, constant part of adaptation

Dynamic systems maintain health (solvency) not by resisting change, but by **flowing intelligently to preserve coherence** over time

Public Private Health Alignment Architecture



Agent Layer : The three agents Patients, Providers and Payers act as local optimizers that evolve to active inference **alignment**

Feedback Layer : **Value – Based reimbursement** , dynamic adjustment of incentives based on observed outcomes

Unified Action Layer : Operationalized **through prevention – as –a-service** , the adaptive intervention policy guided by system intelligence

Solidarity Layer : Public-Private **Equity** Foundation, stabilizes access, absorbs volatility sets population level priors

Shared Observation Model: System-wide perception engine Integrates individual and population signals – **Biofeedback and population health analytics**. Surprises are absorbed.

Shared Generative Model: Forecasts expectations about **health trajectories, costs, and outcomes**

A Distributed Intelligence Architecture - minimizing surprise, maximizing alignment and evolving toward health

Health Bonds - Financing Prevention Through Adaptive Alignement

Health bonds are forward-looking instruments that finance prevention by linking capital to adaptive system performance.

Unlike CAT bonds, which release funds after events occur, Health Bonds align payout with dynamic shifts in population risk and solvency outcomes —for example, modeled through trends in cardiovascular disease risk or other systemic health indicators.

This makes them a **liquidity bridge** that supports long-term alignment, value-based governance, and actuarial rebalancing.

Bond Structure	Description	FEP Alignement
Issurer	Public sector (Govt, Social Security, Multilateral)	Sets the system priors - long-term public goals (health equity, sustainability)
Buyer	Institutional Investors (Insurers, ESG funds, Sovereign Wealth Funds)	Brings free energy minimization logic into capital markets
Capital Use	Funds preventive actions (digital health, screenings)*	System acts on environment to reduce future surprise (KL divergence)
Payout Logic	Based on alignment between expected and actual health outcomes**	Feedback loop rewards coherence between model and reality
Return Basis	Claims reduction, improved solvency, population health impact***	Reflects minimized discrepancy - dynamic value over static trigger
System Role	Dynamic ALM bridge across public-private boundaries	Inference-aligned liquidity flow - enables real-time systemic adaptation

* For example targeting CVD risk cohorts
** For example modeling CVD risk reduction
*** For example reduction in population – level CVD risk metrics

Concluding Remarks

Prevention is Protection

Picture
Nora 2008 Banksy

Health is Wholeness

What is needed is to learn afresh, to observe, and to discover for ourselves the meaning of wholeness."

DAVID BOHM

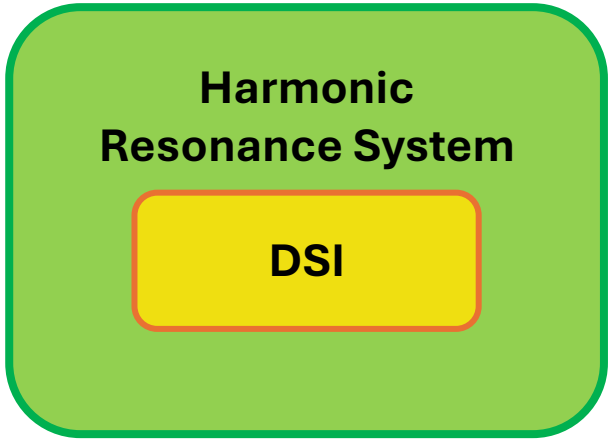
Appendix

DSI: Technical Foundation & Regulatory Implementation

DSI Framework

The Dynamic Solvency Intelligence (DSI) framework is a proprietary application of the Free Energy Principle (FEP), designed specifically for adaptive solvency governance. It integrates:

- FEP for continuous solvency optimization
- Bayesian and Markov Blanket filtering for real-time risk inference
- Public–Private Partnerships for systemic risk-sharing
- Health Bonds as a dynamic tool for longevity risk transfer



DSI is a domain-specific implementation of the Free Energy Principle within solvency modeling.

It is part of a broader cognitive architecture—HRS (Harmonic Resonance System)—which generalizes this logic to other domains, including personalized guidance, behavioral modeling, and dynamic regulatory feedback systems.

Appendix B

Regulatory Impact of FEP-Based Dynamic Solvency Intelligence

Regulatory Reporting Element	Current Approach (Static)	FEP-Based Dynamic Approach
Solvency Capital Requirement (SCR) Reporting	Insurers report SCR periodically (quarterly or annually) with static calculations under Standard Formula or Internal Model.	SCR becomes dynamically updated, reflecting real-time Bayesian risk intelligence through continuous monitoring.
Own Funds Management	Capital reserves remain static until the next formal review cycle.	Own funds dynamically reallocated based on real-time evolving risk profiles.
Risk Calibration Frequency	Fixed calibration cycles typically ranging from 3-5 years.	Continuous recalibration and reassessment of risk factors in real-time.
Reinsurance Impact	Static reduction in SCR, reviewed only periodically.	Real-time solvency intelligence dynamically adjusts reinsurance impacts.
Risk Monitoring & Regulatory Compliance	Compliance assessed through periodic static regulatory submissions.	Continuous compliance tracking, risk management, and automated regulatory oversight.
Capital Management	Capital often trapped in compliance-driven reserves, limiting flexibility.	Capital continuously rebalanced, optimizing liquidity and solvency flexibility.
Stress Testing Approach	Annual or biennial predefined stress scenarios disconnected from live solvency management.	Dynamic integration of stress testing into continuous solvency risk monitoring.
Own Risk & Solvency Assessment (ORSA)	Periodic forward-looking static assessment performed annually or biennially.	Transition to a continuously learning risk assessment system, dynamically incorporating emerging risks.
Solvency Ratio Stability	Solvency ratios fixed until next periodic recalibration cycle.	Solvency ratios dynamically adapt in real-time to changing market and risk conditions.

Intellectual Property Notice

This presentation includes original conceptual frameworks developed by Amir Kamal, including the Dynamic Solvency Intelligence (DSI) model, Health Bonds as inference-aligned financial instruments, and components of the Harmonic Resonance System (HRS).

Thank you! Obrigado!

Questions?

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