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A virtual decision engineering technology for jet engine design systems

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INTRODUCTION

Making informed decisions in the lengthy and labour-intensive design projects, such as jet engine design, requires a proactive approach to quantify dynamics of changes and their 'knock-on' effects on downstream design workflows. This is particularly crucial in earlier stages where the information is imprecise, and frequent changeovers in product functions make it difficult to gather experience on operations. We introduce a user-friendly prototype tool, refers to the *Virtual Propagation Nets* (*VPN*), driven by a simple computational algorithm and deploy it in a real-world engineering case of fan subsystems for aircraft engines.

OBJECTIVES

- Improving managers' 'situational awareness' by showing interactively how alternative design concepts lead to different sets of outcomes, allowing them to identify options that fit best with their strategic priorities;
- Investigating dynamics of design organisation (i.e., the way cross-functional design teams act and interact) on technical product properties (e.g., duration, cost and, performance quality) in an integrated platform; and,
- Identifying effects of interfacing 'hidden influentials' on the risk of change propagation.

THE 'VIRTUAL PROPAGATION NETS' METHOD

VPN offers a cloud-based business intelligence environment for designing an envisaged system and evaluating its structural dynamics in different business settings. This will be accomplished by flexible data elicitation (allowing data to be uploaded from the cloud, or from an external CSV-format file, or entered manually), extensive data visualization (including Network map, Sankey diagram, Parallel Coordinate plot, and Tree maps views), and interactive sensitivity analysis (allowing the user to apply multiple changes concurrently and see its impact in real-time).

The computational core of VPN is computing the Compound Risk ($CRab$) between any component pairs in the system, based on the enhanced version of Decision Propagation Method (DPM) [1]. The $CRab$ of a change between initiating component (a) and affected component (b) is the product of Compound Likelihood (the probability that change in (a) will lead to change in (b)) and Impact (the ratio that approximates component (a) tendency to propagate changes to the other components).

APPLICATION IN AIRCRAFT ENGINE FAN SUBSYSTEM

The case study is composed of 14 agents (i.e. designer, engineer, manager), 37 key design tasks, and 23 key design decision gateways. The network maps before running VPN and after that show the importance of change propagation.

Size of nodes and thickness of links in network map (right-hand side) determines the importance of system component and their connections; e.g., most critical task (D3) and decision (V1) in the system.

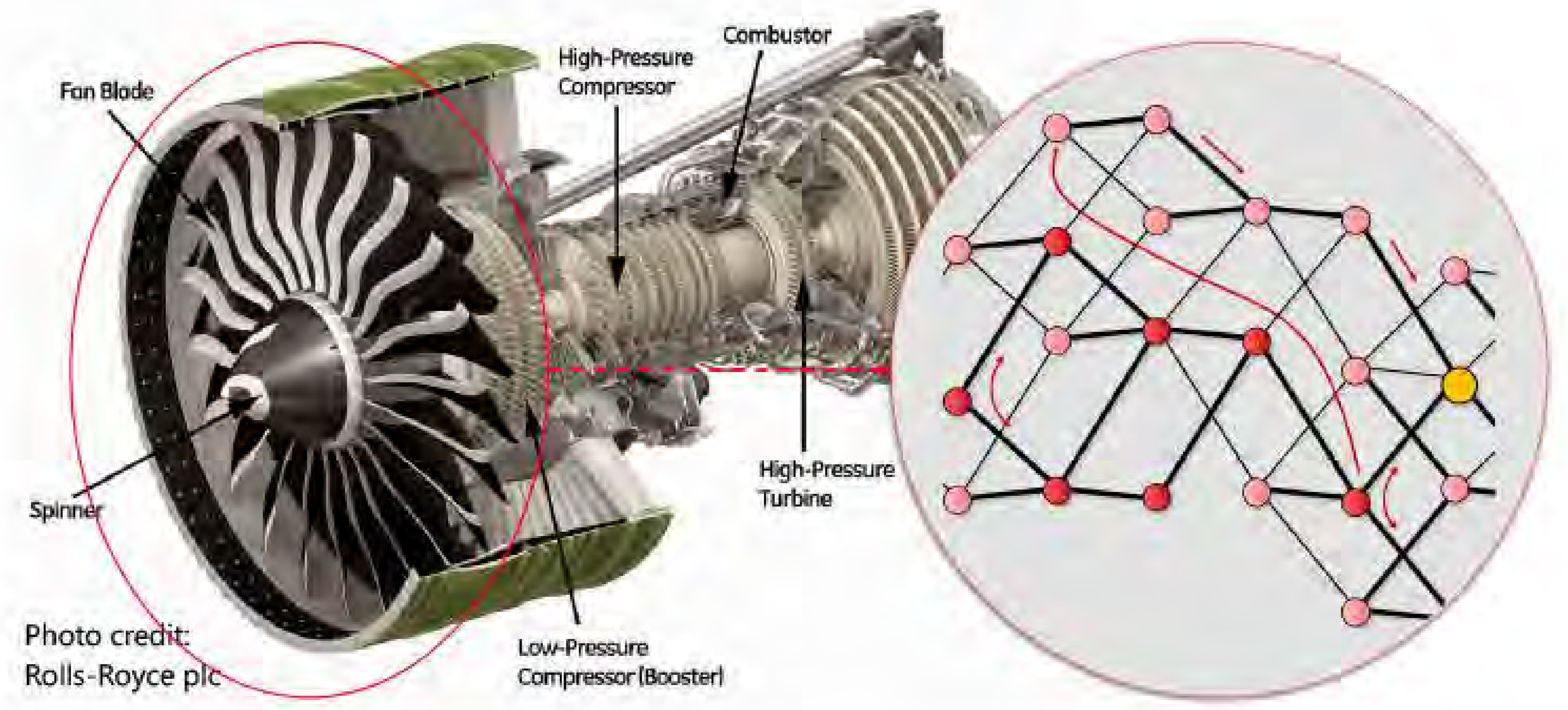
Parallel coordinates visualisation determines a trade-off between design decisions (right-hand) – in terms of their Compound Risk – and at the same time, advise what settings should be made within the design team (left-hand).

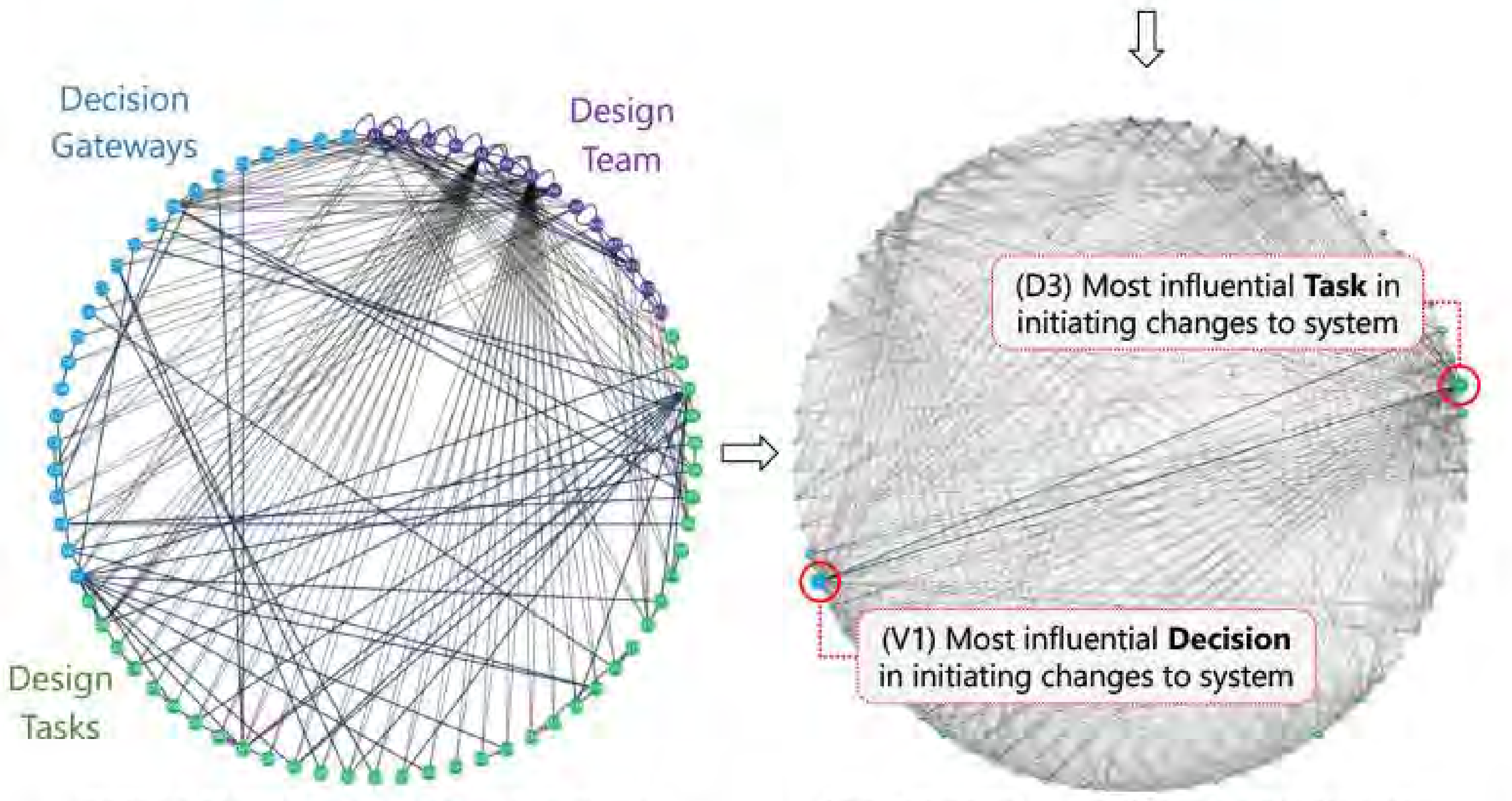
Sankey diagram provides transparency on propagation routes and paths; while there is no direct link between decisions (V1) and (V2), they are intuitively linked through their 'interfacing components' or 'hidden influentials'.

The treemap of task (D3) – the most important task – shows which components in the system it has most influence on, e.g., decisions (V19) and (V13).

IMPLICATIONS

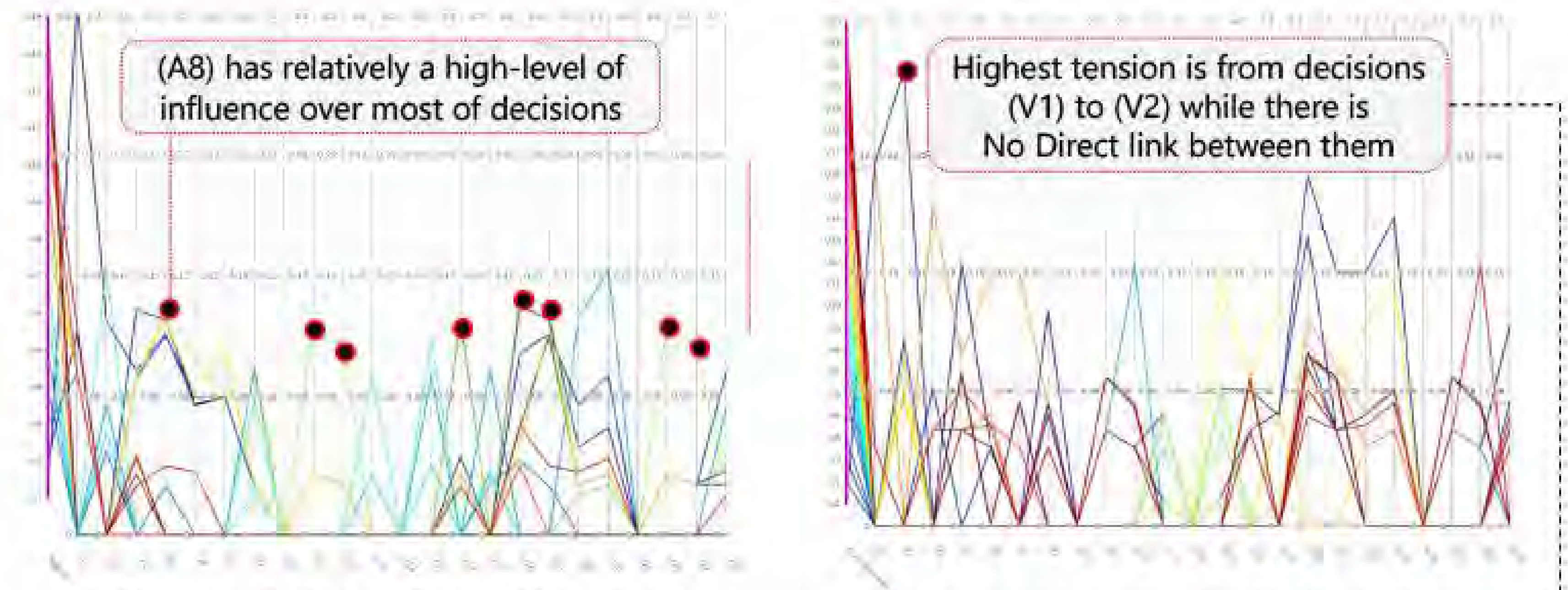
- VPN is the outcome of five years of research with industry partner, and the first research tool incorporating organisational dynamics into the concept of change propagation analysis.
- VPN helps managers direct an unintended consequence of decisions towards something manageable where they have more control to mitigate its effect, considering its indirect dependencies with the rest of system.
- VPN is basically designed for situations where there is not sufficient resolution about business case, to provide transparency on decision-making processes of digital-age while encouraging collaborative design over the cloud.





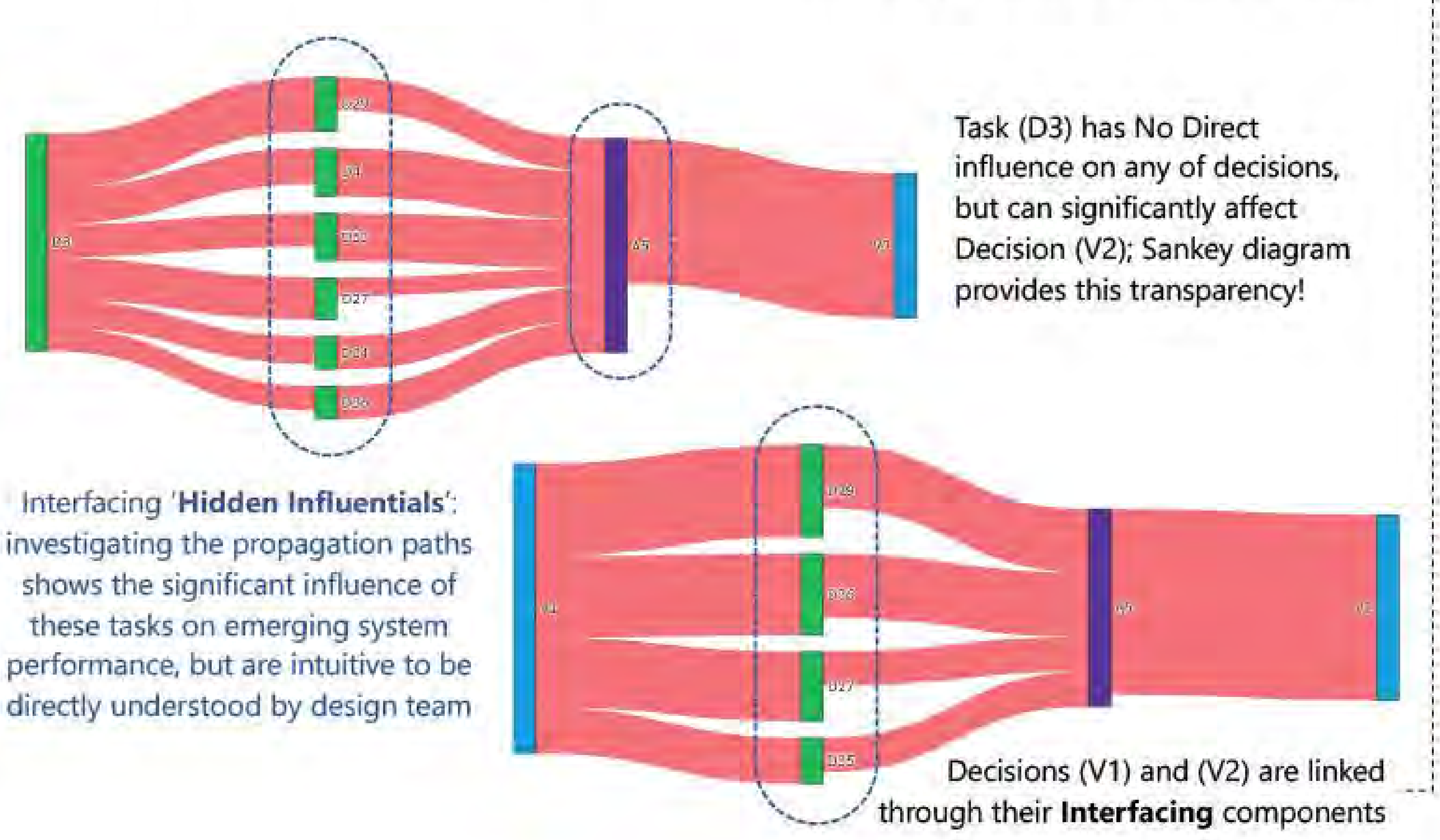
DIRECT Dependency network between Design Team, Tasks, and Decision Gateways

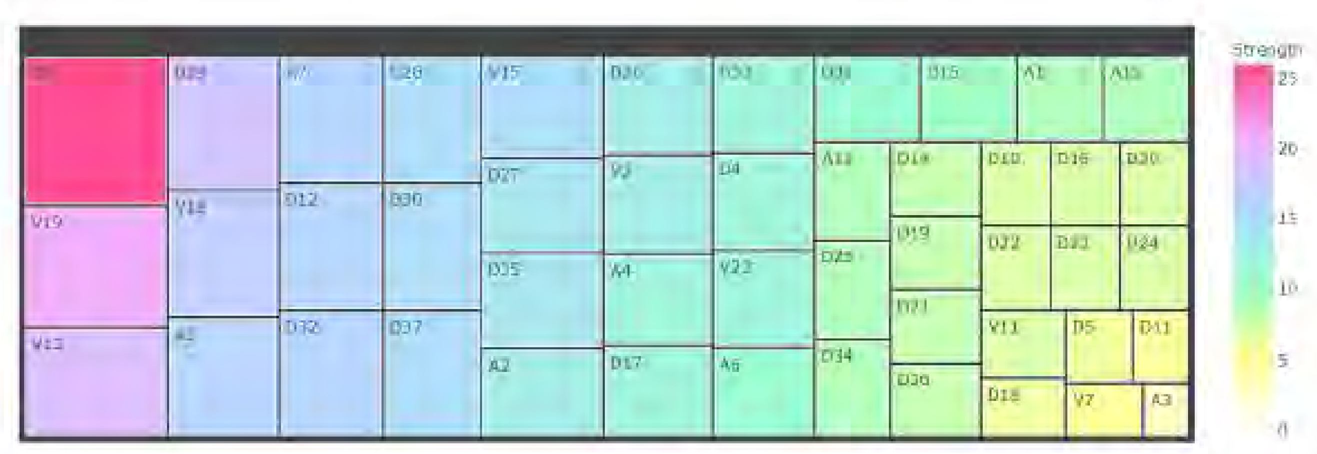
Modelling INDIRECT Dependencies into the network, with 3 propagation steps



Influence of Design **Team** (Y-axis) on Decision Gateways (X-axis)

Mutual impact between **Decisions**: influencing (Y-axis), Influenced (X-axis)





Treemap of D3: this map shows which components in the system (D3) has most influence on