

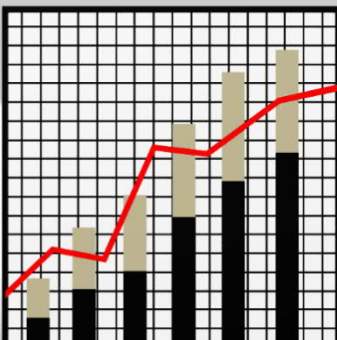
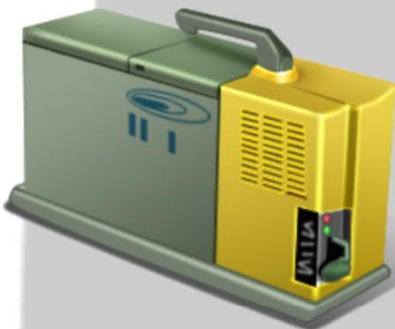
© Dr Michael J Provost 2018

EVERYTHING WORKS WONDERFULLY

An Overview of Servitization and Physical Asset Management

Second Edition - Revised

Dr Michael J Provost



Book Description and Target Audience

Everything works wonderfully is a structured source of guidance and reference information on Servitization and Physical Asset Management written for people at all levels in industry:

- Senior executives considering the expansion of their businesses into the provision of Asset Management services for the products they design and manufacture;
- Middle management wishing to know what needs to be done to look after the assets they are responsible for and who to approach for help;
- 'Hands-on' engineers looking for contacts and advice on detailed tools and techniques.

Academics may also find the book useful as a source of contacts and ideas for research.

As well as giving high-level overviews of many Servitization and Asset Management issues, the book refers the reader to nearly 1,500 papers, presentations, books, magazine articles and websites (much of this material being freely available on the internet) that the author has found useful over the last three decades of working in the analysis, monitoring and Asset Management of gas turbines, railways and clean energy devices.

Everything works wonderfully is currently available as an A4-size soft-cover self-published book. Supporting material and regular book updates are available from the author's website (www.everythingworkswonderfully.com).

Book Contents

Preface and Acknowledgements

A Short Story

Chapter 1: Introduction

Chapter 2: The Business Imperative

Chapter 3: Modelling and Simulation

Chapter 4: Analysis

Chapter 5: Observability

Chapter 6: Time Series Analysis

Chapter 7: Data Visualisation

Chapter 8: More Complex Techniques

Chapter 9: Data Gathering and Software Architectures

Chapter 10: The Practicalities

Chapter 11: Standards and Procedures

Chapter 12: Summary and Conclusions

Looking after Planes, Trains, Clean Energy and Human Health: 23 Important Lessons

References and Websites

Appendix A: Simplified Servitization Example

Appendix B: Power System Example

Appendix C: Solar Panel Monitoring

Appendix D: Human Health Monitoring

A Short Story

Anna Edwards* was a very happy woman. It was her last day as Managing Director of Precision Powerplants* and she was looking forward to a few months of rest and relaxation on the sunny Côte d'Azur with her husband Chris* while she pondered her next move. She knew that she was leaving the company in good shape for her successor (whoever that happened to be: there were several candidates from both inside and outside the organisation who were being put through the on-going 'beauty contest') and felt very satisfied with the progress that the organisation had made on her watch and the transformation that she had overseen.

How different from the situation a decade ago, when she had taken over from the previous incumbent (now long forgotten) who really hadn't understood the business and was forced to retire early. Sales and profits were falling, the share price had flat-lined for several years while the rest of the market soared and the City was muttering that the company had lost its way. A scathing analyst report entitled Always Jam Tomorrow: Beware of Perpetual Promises had ruffled a few feathers and made the Finance Director really angry. Competitors were offering deals that even the company's most loyal customers couldn't refuse and the organisation's reputation for well-engineered power units just wasn't being reflected in profitable sales. Great products (as even the writer of 'that' analyst report had acknowledged) but a lousy business, competing on nothing but price... Anna had taken on the job knowing that she was placing her professional reputation on the line. What should she do? She was starting to get worried.

She decided to bring in Peter Carpenter*, an old friend from university whom Anna admired for his out-of-the-box thinking, no-nonsense tell-it-how-it-is approach and excellent people and communication skills. She sent Peter home to have a 'big think', telling him to stay away from HQ and the alpha gorillas all trying to outdo each other with short-term slash-and-burn fixes which Anna felt were the painful road to corporate oblivion. Peter's brief was simple: produce a plan for getting out of the 'commodity trap' that the company had fallen into and do it quickly before the inevitable crisis came and the whole organisation would be brought to its knees.

Peter had been musing about how to save the company for a few weeks when Sara* burst in to his study as he was casually doodling on a notepad. "The boiler's broken yet again, Peter!" she fumed. "I'll have to cancel my day in town while I wait for the man to turn up to fix it. I bet he won't even have the right parts in his van either! Why couldn't the thing let me know that it was going to break, so I could arrange the repair at my convenience? Why can't it tell the repair man what's wrong? I don't give a damn about boilers: all I want is hot water and a warm house! Looking after it is nothing but hassle!" She stormed out, clearly not at all pleased.

Just then, Peter had his 'eureka moment'. Were customers thinking like this about power units? After all, they had businesses to run and their own customers to serve and didn't want to worry at all about power sources. Were the units that they had bought just an irritating distraction to them, requiring time, effort and expertise to look after that they really didn't have? What if Precision Powerplants used its expertise to look after the units it made (after all, the company had designed and built them, so no-one else should know them better) and charged for the power delivered, not the physical units? Would this idea get the company out of its death spiral?

Peter's mind began racing as his thoughts kept flowing. Customers would probably be happier making regular payments for guaranteed power, which would smooth out 'lumpy' cash flows and could add up over time to more than anyone would pay for 'bare' units. The company could shut out the 'cowboy' sales and service providers who were beginning to eat into its aftermarket business. It could also build up expertise that could be used to make the next generation of power units currently under development more attractive to the market. The organisation might even be able to offer this service to the owners and operators of competing products (after all, the laws of physics were identical for everybody and there were plenty of staff that the company had 'poached' with experience of competitor offerings) and thus eat its competitors' lunches as well. After a few sleepless nights, Peter had even come up with a name for his new initiative: Megawatts, when and where wanted, or MW⁴ for short. Perhaps Helen*, who had just graduated from that incredibly expensive art college in Venice, could help him design a logo...

Peter began to ask questions and research his idea in more detail and discovered that many of the capabilities needed were already in place: they just weren't being brought together into a coherent whole. Peter found people in the organisation who had, despite some management objections and hostility from other co-workers, devised ways of mathematically modelling unit performance and creating actionable information from the data that could be gathered and transmitted from equipment in service: there were also experts in Spares and Repairs who knew how the units should be looked after. All this valuable and unique knowledge had been ignored by Engineering and Manufacturing who just wanted to design, make and sell units before pushing them out of the door ASAP. Something would have to be done to move the organisation from a product to a service mindset, Peter decided, if his idea was to succeed.

Peter managed to book some time with Anna and they met two weeks later. Over coffee and sandwiches in Anna's office, Peter went through the thinking he had been doing and showed Anna the 'elevator speech' that he had quickly put together during the train journey to HQ.



Precision Powerplants and Asset Management

- Precision Powerplants recognises that Customers don't just want to buy and own power units
 - Customers want the capabilities that power units provide (reliable and efficient power), guaranteed over the lifetime of those units
 - Customers can then focus their energies on serving their own markets
- Data gathered from power units in service will be turned by Precision Powerplants into actionable information, using
 - Knowledge of the Customer's business and operational needs
 - Precision Powerplants' detailed power unit knowledge and experience
 - Proven techniques from industry and academia, optimised for power unit management
- This information will be used to enable Precision Powerplants to manage Customer assets more effectively
 - Optimised management of planned and unplanned power unit maintenance
 - Optimised operation of power units and the devices they power
 - *Megawatts, when and where wanted (MW⁴)*
- Result: maximum business benefit for all parties, flowing from the right information made available to the right people at the right time and place

Figure 1: Peter Carpenter's 'Elevator Speech'.

Anna stared at this for a minute or two before turning to Peter with a broad smile on her face. "I think you've cracked it, Peter!" she exclaimed. "I can see it now: our customers want what our power units do, not what they are. If we sell reliable power, not units, our customers will come to us rather than the competition to get what they really want and will pay us a fair price instead of ringing me up at all hours of the day and night demanding yet more concessions."

"You realise, Anna, that this will mean the company will have to change its thinking, from top to bottom." said Peter. "For example, we won't be able to rely on profits from spares sales to offset any losses made on unit sales because spares usage will appear on our books, not the customers'. Our units will have to consume fewer spares than they do now. Engineering and Manufacturing will have to listen to inputs from Spares and Repairs and we will need to put comprehensive and robust systems in place to gather, store, process and output information about how our units are working in the field. It's a whole different mindset and some of the current managers won't get it." "Don't worry, Peter!" retorted Anna. "Those that don't buy into this will either have to change their thinking or leave. I'll need a plan, a budget and a list of the people you think you'll need to help you for the next Board meeting, to which you are invited."

"Would you like to be the Director in charge of this?" Anna added. "Of course, Anna!" exclaimed Peter. "This looks like a real challenge and, with your backing, we can build this into something that will completely transform the organisation. It will also get me away from all the jobs that need doing at home." They both laughed. "What do you think of Helen's design for a logo?" enquired Peter, as he turned to leave. "I thought it showed real flair and imagination." "That could be your first decision." replied Anna. "Let's discuss it with Marketing before the meeting."

The Board poured cold water on Peter's presentation, but Anna insisted that Peter's initiative had to be pursued, made Peter the Board member responsible and gave him her full support. The next few years were hard, but genuine progress was made by Peter and his team and even the most sceptical Board members couldn't brush aside the company's much improved financial state. Peter set up a subsidiary to ensure that the initiative grew without being stifled by the old guard, who saw their power and status threatened and pushed back hard. As predicted, those who didn't fit into the new culture either left voluntarily or were asked to go. MW⁴ grew rapidly: many managers and employees saw it as an opportunity to escape from the limitations imposed by existing corporate structures, the company was able to recruit many good people with the skills it required and those involved relished the chance to contribute fresh ideas. Eventually, as the market responded positively to the new way the organisation conducted its business and built more constructive relationships with its customers, sales and profits rose, the City started to take notice and the share price began to rise rapidly. Anna knew that she had turned the corner when she overheard a long-serving manager talk about product sales as the entry ticket to the true market, which was satisfying real customer needs rather than merely selling clever bits of metal. Customers began to ring Anna up with fulsome praise rather than complaints and the press and investment analysts began writing long, glowing articles about the 'new' Precision Powerplants, which began to be seen as a model company that pointed the way to the future rather than a relic of past glories. Peter and Anna were in great demand to speak at industry and government events as other companies sought to emulate Precision Powerplant's success. Marketing even produced a very concise summary of MW⁴, inspired by Japanese Haiku poetry.

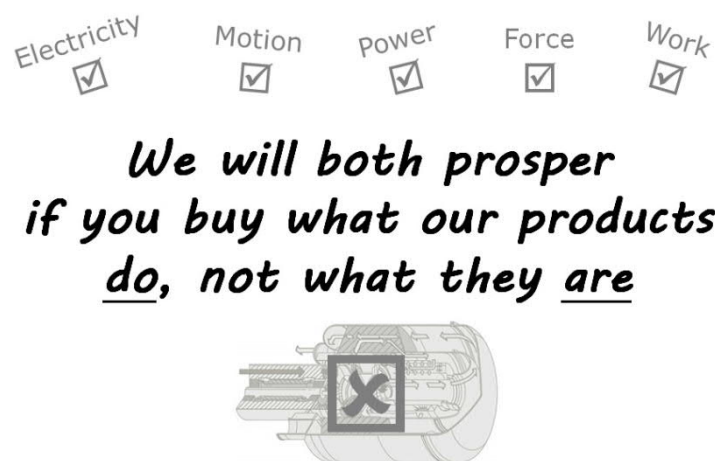


Figure 2: Servitization in seventeen syllables.

Anna was just finishing off her last cup of 'canteen cappuccino' when Peter breezed in. "The Oracle has spoken!" he exclaimed. "I am the new boss! It wouldn't have happened without your unwavering support over the last ten years, Anna. Thanks for everything!" Anna stood up to shake Peter's hand, knowing that the company would grow and prosper under Peter's wise guidance. As she left for the last time, a thought struck her as she turned on the windscreen wipers: perhaps she should use the proceeds from selling some of her share options to buy that villa near Saint-Tropez that Chris had seen advertised in the FT. It would make a good surprise birthday present for him and provide a much-needed bolthole from the atrocious UK weather.

* Note: the company and characters are fictitious, but the scenarios are based on experience.

Looking after planes, trains, clean energy and human health: 23 important lessons I've learned the hard way...

This chapter was originally produced for the Society of Automotive Engineers (Jennions 2014): it has also been presented as a paper at the IET/IAM 2014 Asset Management Conference in London, UK (Provost 2014). It is reproduced with permission from both the SAE and the IET.

1. It's what an asset does, not what it is, that is important

Train, bus, aircraft and truck operators really want the ability to carry passengers and freight, not planes or vehicles. Utilities really want clean and efficient electricity generation, not turbines, boilers, etc. Manufacturers of electronic equipment really want components placed on a circuit board, not the machinery that does this. Bottling plants really want filled bottles, not bottle-filling machinery. Airlines really want thrust, not jet engines. The literature is full of examples of the seismic shift from customers wanting the asset itself (and negotiating the price down as far as possible to reduce capital expenditure) to them wanting the capability the asset provides (and being more willing to pay a predictable, de-risked operational cost that can more easily be passed on to their end customers). Providing an Asset Management capability and ensuring that this is delivered to your customers consistently and efficiently over the lifetime of the assets you make, is a very lucrative, stable and long-lasting business proposition which you need to fully embrace before your competitors and other third parties do so.

2. Asset Management is a business issue

It is not just another IT problem; it impacts the whole structure of your business and the way you think about and relate to your customers. Every aspect of a business, including strategy, development, management, partnerships, mergers and acquisitions, projects, marketing, sales, engineering, IT, communications, resource planning, configuration management, logistics, training, field support and customer billing, is profoundly affected.

3. Without senior management support, Asset Management goes nowhere

The changes to your business that Asset Management demands are so huge that, without the full support of management at the very highest levels, it will never get 'off the ground', never mind succeed. The vested interests, new and expanded mind-sets and understandings, changes in existing organisational power structures and general corporate inertia can only be overturned by committed leadership from the very top of your organisation.

4. Know your assets

A deep understanding of your assets, the business contexts and ambient environments they operate in, their failure modes, frequencies and consequences and how they need to be looked after is much more important than knowledge of IT, databases and analysis methods. Your business has knowledge gained during the design, development and production phases of the assets you make and sell that can be used to generate value for the business time and time again over the whole life of those assets, rather than being used once only during manufacture.

5. Asset Management needs to be incorporated at the start, not brought in later as an 'add-on gimmick'

Don't let the need for low first cost destroy the greater need to create lifetime value. There is a conflict to be resolved between the production demands for low first cost and high product and spares sales volumes and the Asset Management needs for data gathering hardware and more finely-tuned product and spares offerings that may be the best solution for your customers. Many production-focussed organisations see Asset Management as a threat, both to sales of new products and to sales of spares; many Asset Management initiatives have been deliberately strangled at birth because of the perceived loss of spares revenues (or even new products) that could result. Mechanisms need to be found for the long-term rewards of Asset Management to be fed back to the production arm of the business, which, after all, provides

the 'entry ticket' for all future Asset Management value streams. Retrofitting sensors and remodelling organisations are very expensive and time-consuming processes.

6. Break down the silos, open your mind and look for what your customers really need to help them make money and serve their markets better

The benefits of Asset Management may not be where you first thought. Bringing all the measurements and analysis together into one 'single source of truth' can produce many savings and unexpected value-creating synergies. Once the measurements are in one place, it becomes much easier for you to weed out unnecessary duplications, see the whole picture across both individual assets and asset fleets and carry out analyses that go beyond the initial aims of monitoring asset health and operation and move towards answering the real questions that your customers may be asking about their businesses.

7. Share to gain

Partnerships between all interested parties create the 'win-win' situations that ensure success. Customers and end users have deep knowledge of asset performance in their own operations, but lack information about the same assets used by others elsewhere. Asset owners have a vested interest in 'cradle to grave' asset performance and maintenance, but usually lack asset technical and operational skills. Sub-system suppliers have deep knowledge about the performance of components that they produce, but often fail to see their operational contexts. IT and communications vendors keep abreast of the latest developments in their fields of expertise, but lack asset technical and operational experience. Asset manufacturers and systems integrators have access to the asset design, modelling and analysis tools and data, as well as the ability to bring all the above parties together; however, they will only succeed in offering Asset Management services to their customers if they offer the means for everyone involved to collaborate for mutual benefit.

8. Never underestimate the persuading you will have to do, at all levels in your organisation, or the power of the 'heroes' who feel threatened by strange new ways of doing things

No-one ever got fired by doing what worked yesterday, whereas plenty of people have lost their jobs by deviating from the status quo. Many people, from upper management to those at the 'sharp end' of your business, will feel that their jobs are being put at risk if their unique 'head knowledge' and ways of working (which will have made them key organisational players and offered lucrative opportunities for enhancing their power and earnings) are made more generally accessible to others by Asset Management initiatives. They will fight the changes brought about by Asset Management with all the energies and internal politics that they can muster. If the person who needs to act on Asset Management information isn't convinced by it, you have wasted everybody's time and money.

9. Beware of people who just ask for 'data' and/or confuse data with information

Many people don't know what they want to do with data. Help them to articulate what they really need, by talking about identifiable measurements and focussed information requirements, not 'data'; this approach rapidly improves the chances of success. People can rarely explain to you what they need on a 'blank sheet', but are much more willing and able to provide constructive feedback when you show them examples of what can be done.

10. Asset Management is a chain, from sensor to business action

The process of data gathering from sensors fitted to assets, data gathering and transmittal to a central location, data storage, data visualisation, data analysis and problem diagnosis, followed by assembling together the right resources (information, tools, spares and qualified people) at the right time and in the right place to take the required actions to keep your customers happy is a complex and fragile chain. If any link in this chain breaks, no matter how trivial, the whole process collapses.

11. Don't put the data cart before the business horse

Many Asset Management initiatives start with specifying the data to be recorded on assets, without thinking about what is to be done with it. This usually results in the wrong data being recorded and/or transmitted at the wrong times and frequencies and opportunities for gathering what data is really needed are lost. Alternatively, the request is to 'measure everything, all the time', in the belief that transmission bandwidth is infinite, IT is zero-cost and the question of what is to be done with the data will be resolved eventually. This usually results in unmanageable data volumes in which the real signals are lost in a quagmire of digits in a database. Business needs drive analysis requirements, which in turn drive data gathering (both sensors and frequency of data gathering and transmittal). You can measure anything; you could measure everything; you should only measure what creates value.

12. Keep it simple

The Asset Management literature is full of analysis methods that are poorly explained, steeped in obscure mathematics, lack clarity or obvious engineering relevance and seem to be aimed more at demonstrating the cleverness and academic credentials of the author(s) than enlightening humanity. The end result of any analysis has to be action, usually taken by someone with practical rather than academic intelligence. Techniques such as applying thermal paint to a component that changes colour when that component overheats are considerably cheaper and more quickly and easily understood by those in the workshop (who may not have much time to understand and fix problems) than more complex data gathering, transmittal and remote analysis. The smartest analysis or visualisation in the world is useless if nobody else understands and trusts it enough to act on it.

13. A physics-based asset model is a very powerful business and technical tool

It builds the foundations for full understanding of asset and business dynamics. Such a model (or set of models) improves communication within and between all interested parties both inside and outside your business and provides consistent and traceable predictions and baselines of asset, project and business performance. It also provides you with rapid assessments of how assets should behave in different environments and operational contexts and forms the basis of fast, consistent and accurate assessment of asset performance in the field. Physics-based asset models can support the application of many advanced analysis techniques that would not otherwise be practical and enable the optimisation of asset technical and business performance, profoundly improving the cost, speed, efficiency and effectiveness of asset development and in-service support.

14. If at all possible, compare all your asset measurements to a baseline, which ideally takes account of all known external drivers of the recorded values (e.g. load variation, ambient condition changes and other quantified effects)

There is always a baseline somewhere (from a number in someone's head to a full physics-based asset model) against which measurements can be compared; find it and make it visible, so everybody can easily see what is good and what is bad. Residuals (the differences between measurements and baselines) are much easier to understand and analyse than raw measurements and provide order-of magnitude improvements in the 'granularity' of your analyses that significantly increase the timeliness and effectiveness of asset health and operational assessments.

15. A good measurement and/or analysis visualisation, tailored to the person you are talking to, will make all the difference

Some visualisations (such as time series, X-Y plots, bar and column charts, dashboards, alerts and interactive drill-down) will always be useful, while others (like mapping, statistical displays, reports and system synoptics) may find more specialised niches in the organisation or with customers. Use visualisation to persuade and excite; people rarely know what they want to see and how they want to interact with the data, but will provide enthusiastic feedback when you can show them examples of what can be done.

16. The appropriateness of the analysis is more important than the 'bigness' of the data

'Big data' is all the rage, with many commentators and IT consultants seeing the advent of massive unstructured databases, off-the shelf analytics and cheap 'cloud' storage and processing as panaceas for most Asset Management issues. While such approaches can work well in the 'softer' areas of retail, social science and financial asset management, there are more appropriate tools and thought processes that you can and should use for analysis of the performance and operation of physical assets. The use of 'smart analytics' to back-calculate what a good physics-based model of the asset could have told you gives a false sense of progress and potentially confuses failure signals with the noise of operational variation. 'Black box analytics' also make it too easy to 'overfit' data (producing an analysis that is not valid for new data when it arrives) and/or find spurious patterns or correlations in large datasets that don't make logical sense. Asset Management must be based on sound technical and business logic; subcontracting the thinking to the latest IT hype can quickly lead you to expensive failure and loss of credibility.

17. Cost is not value: keep reminding the cost-cutters of this

Many people confuse the cost of a component with the impact it has on your customers' operations, with the result that many items that are critical end up being ignored purely because they are technically undemanding, cheap or generally 'boring'. The \$1 component that generates costs of \$1,000,000 when it goes wrong is worth monitoring and taking care of. Many of the best Asset Management programmes owe their success to looking after the 'boring but important' items in their asset inventories very well.

18. An asset measurement without a timestamp (preferably GMT/UTC, which avoids time zone and daylight saving time issues), unique asset identifier and some measure of operating stress and environment is a random number from which useful information can only rarely be retrieved

A sensor reading from an asset means nothing if you can't place it in context or relate it to other readings from the same or related assets.

19. Inadequate asset configuration knowledge and/or asset configuration control makes meaningful Asset Management impossible

There are significant differences between the 'as designed', 'as built' and 'as maintained' state of all your customers' individual assets once they have been deployed in the field; these differences are critical and can be the source of many Asset Management failures, from not understanding data signals to delivering wrong spare parts to the maintainer in the field. Watch out for undocumented 'temporary' fixes and modifications to assets and working practices that solve short-term issues but cause damage and play havoc later.

20. Some people just don't 'get it'

Either re-educate them or remove them. Asset Management demands such a huge change of organisational mind-set that it is inevitable that many people at all levels in your organisation either can't or won't see what it's all about. At best, the unbelievers will sit on the side-lines and hope you will go away; at worst, they will actively sabotage the necessary business process re-engineering. If necessary, spin off Asset Management into a separate organisation to allow it to develop and grow and free it from malign influences.

21. Don't assume anything

It's easy, given the massive complexities of Asset Management, for you to assume that the data, people, processes and tools you will need are (or have been) thought about by others and will be made available for you to use. If you don't ask, you don't get.

22. Know the limits of what you know and learn to appreciate the contributions everyone at all levels can make to the whole Asset Management process

No one person has all the answers and Asset Management insights can and do come from anywhere, both inside and outside the business. There will be many twists and turns in your Asset Management journey and changes in emphasis as you learn what is really important and

what really will generate value. Data is not information. Information is not knowledge. Knowledge is not wisdom. Listen to anyone and everyone. Humility is a virtue; it opens you up to the knowledge and experience the people you have to work with can bring to the Asset Management enterprise.

23. Push, but be patient

Success breeds more success, interest and enthusiasm will grow, the pace will quicken and recognition and rewards will flow eventually (sometimes from the most unexpected directions...). It can be like a game of Snakes and Ladders; there are many ups and downs on the road to success.

Examples and Stories

Over the last thirty years, I have come across many examples and stories where success has depended on application of the lessons I have detailed above. They include:

In the 1970's, the chairman of a well-respected European airline, when hearing that an experimental aircraft engine Condition Monitoring program could have prevented a turn-back of a wide-body airliner if its output had been heeded, demanded that it be put into fleet-wide use immediately. He didn't require formal justification; he knew that his airline's technical and financial performance and reputation would benefit if this was done.

Since the 1980's, many airlines have used engine monitoring to optimally dispatch aircraft, sending those with 'hot' engines to cooler destinations and vice-versa. This strategy extends engine on-wing lives and results in fewer engine over-temperature events, avoiding service disruptions.

Data collection doesn't have to be expensive and complex. In the 1980's, one major European airline equipped all their check-in desks worldwide with optical character readers, so that passenger service staff could feed engine and aircraft data to their main engineering base from cockpit printouts when they were not serving paying customers. A worldwide data gathering network, riding on the back of the ticketing system, was created for a few tens of thousands of dollars.

Another major European airline has amassed so much data on the performance of the aircraft, engines and other sub-systems that they operate that suppliers regularly use this 'treasure trove' to initiate design changes to in-service aircraft. In one case, the hydraulic system of a wide-body aircraft was completely redesigned based on data from one take-off during which an uncommanded pitch down was recorded.

In the 1980's, one somewhat sceptical power station manager in the UK shut down a large steam turbine on the basis of the output from an experimental vibration monitoring system. When the turbine was opened up and inspected, a crack was found in the main shaft that would have resulted in catastrophic failure and potential fatalities had the turbine run for another thirty minutes. He was convinced!

The aircraft gas turbine industry depends heavily on physical models, which have reached such a degree of accuracy and sophistication that they form the basis of operational and maintenance forecasts that can be produced for each customer covering the whole life of an engine fleet. Thanks to these models, engine development programs are now used to validate the engineering understanding the models have already produced, rather than generating that understanding 'from scratch', resulting in huge savings of time and money. The models also create foundations for a great many sophisticated analytical approaches to Condition Monitoring.

One major gas turbine manufacturer found it necessary to create a separate company to develop Condition Monitoring and other aftermarket service capabilities in order to prevent the prevalent 'manufacturing mind-set' killing off the ideas being developed before they had a

chance to prove themselves.

There are many examples in the railway industry of sensors being fitted for one purpose generating more value when being used for something else. For example, air suspension pressures are used to produce estimates of passenger count, while electrical faults and wheel slip protection system activations observed across a fleet are mapped to indicate areas of the rail network that require maintenance action and data recorded for potential incident and accident investigations is used to find the causes of service delays and attribute penalty payments appropriately.

One major UK rail operator has eliminated the need for passenger door fault-finding activities at their engineering depots by relying entirely on the data such as opening and closing times and door actuator motor currents from millions of door operation cycles gathered from the in-service train fleet to accurately predict and schedule any necessary door maintenance activities.

Another UK train operator transmits a 'mimic' of each driver's control panel to a central control room in real time, enabling support staff to give timely advice to drivers and other train crew.

One major UK truck manufacturer discovered that the sensors used to monitor diesel engines can be used to monitor driver behaviour. They now offer a service that uses this data to progressively improve driving styles, producing significant reductions in trip delays, accidents, insurance premiums and fuel consumption. The customers and drivers share the benefits, producing the necessary positive feedback to ensure success.

One major Formula 1 team uses Condition Monitoring data to model the performance of each and every car in a race in real time, using these models to predict race outcomes and run 'what-if' analyses to optimise their refuelling, choice of tyres and pit stops.

Many van and truck businesses now use real-time GPS and other vehicle data to track fleet performance, thus reducing costs and improving customer service. At least two major car manufacturers are extending this philosophy into the consumer arena, to offer comprehensive real-time advice and support to private motorists. This is felt to be particularly useful for battery-powered private vehicles, to overcome 'range anxiety' and instil confidence in new technologies.

Almost all road vehicles are now fitted with comprehensive on-board diagnostics, reducing maintenance times and costs. Even owners with the right smartphone 'app' can now access detailed real-time information on the performance of their vehicles.

Remote diagnostics are crucial for both maintenance and operational planning of a wide variety of critical, high-value or difficult-to-reach plant, including petrochemical and other process plant, water, gas and electricity networks, wind turbines (particularly those placed offshore), power stations, backup power units for mobile phone masts, etc.

Human health monitoring is becoming increasingly important, as populations grow older and healthcare resources are stretched. I have successfully monitored my own blood pressure, weight, urinary function, food intake and exercise for nearly a decade, using very simple tools and visualisations to achieve huge improvements in my health and wellbeing and possibly saving my life in the process.

These are just a small selection of the many success stories that are emerging as companies in many industrial sectors begin to appreciate the power of knowledge about how their assets they make and use are behaving in service and how this knowledge can be used to improve their businesses and satisfy their customers.

Conclusions

This chapter summarises what I have learned about Servitization and Asset Management during the last thirty years of my professional life. Crucially, Asset Management has to be business focussed, because a business is affected by what an asset does, not what it is. It's also very beneficial to take a broad view, since the benefits of Asset Management may not lie where you first think; building on this, data integration gives synergies that create unexpected value and delight customers. Asset knowledge is critical; physics-based models build the foundations for full understanding of asset and business dynamics. Things must be kept simple and visible, if you want your efforts to be accepted and acted on. It must always be remembered that cost is not value; the cost-cutters need reminding of this frequently. An Asset Management business cannot be created without developing the three key ingredients; people, processes and tools. Human factors must never be underestimated, because they will dominate your efforts. Finally, I've always found that perseverance pays off, both personally and professionally.

References

- Jennions, I. eds. (2014). Integrated vehicle health management: implementation and lessons learned. Warrendale, PA: SAE International.
- Provost, M. (2014). Looking after planes, trains, clean energy and human health: 23 lessons I've learned the hard way. IET/IAM 2014 Asset Management Conference, Millennium Gloucester Hotel, London, UK, 27th-28th November 2014. Stevenage, UK: Institution of Engineering and Technology.

About the Author



Dr Michael Provost has recently set up Michael Provost Consulting Ltd to both help and inspire businesses to make the journey described in the Short Story and to teach others what Mike has learned during nearly four decades involved in the modelling, simulation, analysis, condition monitoring and management of physical assets and contributing to the many business transformations that Servitization involves. He spent twenty-seven years at Rolls-Royce plc working on the modelling and analysis of civil aero-engine performance, aero-engine Condition Monitoring (where he won the Chairman's Award for Technical Innovation in 2000 for his analytical contributions to Rolls-Royce's COMPASS™ Condition Monitoring system), corporate strategic planning and advanced civil aero-engine and More Electric Aircraft systems design. He then spent two years at Data Systems & Solutions Ltd, a Rolls-Royce plc spin-off company, working on applications of aerospace Asset Management techniques in areas such as railways before spending five years at Bombardier Transportation where he led the team developing the engineering analysis and visualisation methods used in Bombardier ORBITA™, a world-leading railway Asset Management system. He then spent five years at Intelligent Energy Ltd., a company focussed on the development and commercialisation of fuel cell systems, where he was responsible for guiding the development and roll-out of a range of Asset Management techniques across that company's automotive, consumer electronics and distributed power product lines. Mike applies the principles he has developed for monitoring planes, trains and clean energy assets to the management of his own health, with very beneficial results.

Mike graduated from Trinity College, Cambridge, in 1976 with an honours degree in Engineering and gained a PhD in Thermal Power from Cranfield University in 1994. He is a Fellow of both the Institution of Mechanical Engineers and the Institution of Engineering and Technology and is also a Member of the Institute of Asset Management.

Mike lives in Nottingham, England and can be contacted by telephone on +44 (0)7811 944990, via email on mike@michaelprovostconsulting.com or via LinkedIn®.

© Dr Michael J Provost 2018