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CHAPTER 1

Data Analysis and System Integration

What all technical systems or applications have in common is data, and for data to serve some purpose there must be analysis of that data to achieve a goal; that goal most generally being System Integration. While you will encounter many systems in this book--another way to say many "Technical Applications", the focus of the book is really on the subject of DATA ANALYSIS. In the history of science and technology the single closest recognized discipline of education and application to what is considered Data Analysis today is that of Numerical Analysis. {Sometimes the discipline is called Numerical Methods, and years ago as large scale computers became the tool of technical and scientific research, the closely allied field of Operations Research developed knowledge and skill to mold the discipline of Numerical Analysis into engineering, computer science, and technology.}

We technical workers who lived and worked through technical applications with computers of the last 50 years, the half a century of what will later in the book be called "The Digital Atomic Age" because digital did for technical applications with computers what the atomic bomb did for science, also saw Numerical Analysis grow and develop from applications to large scale vacuum tube and analog computers, through the minicomputers of transistors, and then into the microcomputers of integrated circuits (ICs). This is not to say that some person or group instigated a plan for this Digital and Digital Computer revolution often at the highest technical levels riding on the back of Numerical Analysis, unlike the changes instigated by Bill Gates and his Microsoft Empire {we will not now get into the borrowing Microsoft did from the hard work of the MAC empire}; but it rather just happened as the natural evolution of science and technology of many diversed applications like physics, mathematics, engineering, computer and other electronics hardware and software.

Just the solution of a problem of physics was numerical analysis without being considered as such. The system was analyzed whether it was a simple falling body, a pendulum, a bouncing ball, or the path of a missile; a drawing was made to represent the system with all the known data recorded on the drawing; the applicable physical equations of motion were applied; and then a numerical solution was calculated. Quite often a more detailed problem involved some error analysis between the calculated and the standard as for example when in a physics lab we were using the famous oil drop apparatus of Millikan to determine the charge of the electron as close to the known value of 1.6 X 10^-19 as possible. {Note we will use in this text the notation of the MATLAB language.} So the error analysis gave us a percent comparison between our experiemental calculations and the known standard. And what we were really doing without any such real noble goal as what Lord Kelvin said {"It is not scientific until you attach a number."}, was to understand and integrate a technical problem by attaching a number that had more significance to us than for example E = m X c^2 or Newston's second law of Force is equal to mass times acceleration (F = ma). In fact, we might say in looking back on the early history of science and classical physics, that Newton when the apple under the acceleration or force of gravity fell from the tree on his head, or when he formulated with much thought, application, and numbers, the second law of motion, was the process of numerical analysis, or Data Analysis.

You will find in the course of the reading and study of this book that two systems dominate the material--airplanes and missiles; but it is hoped that you will see up front, and foremost, that these two now very complex systems as seen in the Technical Applications to the Boeing 787, the General Dynamics F-16, and the Space Shuttle which is now a Space Airplane robotically controlled, illustrate techniques and tools of DATA ANALYSIS. {Also we must write about what we know from experience and having retired from General Dynamics as a Flight Test Engineer on the F-16 and from Raytheo as a Principal Systems Engineer, testing the missiles that carried the KW and EKV into the exo-atmosphere to shoot down incoming ICBMs, the material naturally evolved into a focus on missiles and airplanes.} Yet you will find telemetry, flight test, communuations, and other modern systems, once agains as illustrations of DATA ANALYSIS.

Lastly somethig must be said about the foundation of mathematics in the history and evolution over the last 50 years of numerical analyis for data analysis. You will read more about this in later chapters, especially the one on "The Digital Atomic Revolution", but it can be simplied by considering math as passing from an emphais on differential equations {which of course like all motion and physical phenomenon itself are analog} to the matrix of linear algebra; of course with mathematical techniques like Taylor series and the LaPlace transform to convert from an analog to a digital format, or from differential to linear format. That is where MATLAB in technical computer applications, much like Microsoft in total computer applications, has ridden the back of the Digital Atomic Revolution: MATLAB has provided the tools in a single concise language {many statements called commands like "diff" to differentiate and "FF" for the fast fourier transform of the LaPlace equation} to easily provide calculations in analog, digital, and both. Then you throw in the simulation part of MATLAB with "Simulink", the built in simulator of MATLAB, and you have a language and software, albeit quite expensive except for large companies except for the student version used primarily in this book, and MATLAB can do just about anything for you, including your calculus and linear algebra homework, except cook your meals. Even as Microsoft developed into the more popular software than MAC while not being at all any more functional, so other software today like FORTRAN, Mathematica, or BASIC depending on the technical application can be as fucntional as MATLAB, we just have in MATLAB and Microsoft the more popular means of communicating with our technical, social and work environment.

Quite often modern and complex electro-mechanical systems consists of many systems; for example the F-16 operates centered around over 20 distinct computers and systems like the weapons control systems, the fire control system, the flight control system {each having its own quad-redundant computer or in the case of the FCS a system or 4 computers--the CADC, the FCC, the ECA, and the PSA[1]}, the engine warning systems, the engine control system, and on and on. And almost as often the modern in design, system integration, and flight test is that well designed partial systems work quite well independent of the aircraft {that is, in the integration lab}, but do not work as a whole in the total system of the aircraft. This was not so much a problem in the F-16 as it was after design

1. This was in the A and B models before the C and D models which started at block 40, and before the analog Flight Control Computer was converted to a digital flight control computer.

of the first block 1 system was further developed through the years in a block system, going from block 1, to 10, all the way up to 40 and beyond; so that any subsequent total systems integration and development problems such as engine warning, direct battery power to the flight controls and an auxiliary generator just for the flight controls, secure voice, and even newer ECM and weapons were wisely programmed through the years as large scale modifications. This was not the way the Lockheed Martin C-130J, an all computer controlled aircraft, program was designed and developed, so that for approximately one year after exit from production the bugs of total systems integration {the well designed parts working together as a whole} were still be worked out. One obvious case in point since LMC had previously sold the wind tunnel at Marietta to Ford Motor Company and no tunnel model of the C-130J was tested, it was a surprise to all at the total system flight test when the props, the composite airframe, the engines, and aerodynamics of the J model departed from the flight history of many years of other models of the C-130; in fact, departed during a stall with a slip right of approximately 5,000 feet. That is a hard way to learn about a further need of systems integration based on data analysis of wind tunnel data.

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