Marijana Borić: "Faust Vrančić: 400 years after the publication of his work *Machinae novae*"

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Abstract

Faust Vrančić (Šibenik 1551 - Venice 1617) was one of the most versatile Croatian humanists-polymaths who, with his scientific, intellectual and diplomatic-political activities during the transition from the 16th to the 17th century, left an indelible trace not only in Croatian but also European science and culture. Since his opus includes philosophical, linguistic, historical, hagiographical and natural scientific works in Latin and Croatian, he is the subject of research of a wide circle of experts from various scientific disciplines. This article presents, from several aspects, Vrančić's most famous work, the techn(olog)ical manual *Machinae novae* and examines, in a scholarly manner, his importance for the development of technology and contribution to the European intellectual culture of that period. The article also explains Vrančić's education and coming of age into one of the foremost techn(olog)ical writers of that period and analyses the most important characteristics of the structure and contents of *Machinae novae* through which Vrančić acquired worldwide fame. The methodology and content of the work is compared with the Western Renaissance scientific/scholarly and techn(olog)ical tradition.

Key words: Faust Vrančić, Croatian scientific heritage, Renaissance, history of technology, inventions

Introduction

The 400th anniversary of the publication of the book *Machinae novae Fausti Veranti Siceni cum declaratione Latina, Italica, Hispanica, Galica et Germanica* (Venice, 1615/1616), one of the capital works of Renaissance technology and the first techn(olog)ical manual written in territory of modern-day Croatia, is an opportunity to discuss the importance of this work and its author. The affirmation of human personalities in different forms is a well-known heritage of Humanism, and Faust Vrančić was precisely an example of the successful Renaissance type of man, the so-called *homo universalis*. Vrančić (Šibenik 1551 - Venice 1617) was one of the most influential persons in the Hungarian Kingdom of that period, a secretary to the emperor Rudolf II, bishop, engineer, designer, lexicographer, while he also wrote historical, philosophical, theological and literary texts. With his education, ability and persistence Vrančić attained high positions in public life: social, political and ecclesiastical. Through his works, Vrančić outlives his time. Two works of permanent value should be emphasised, his penta-lingual dictionary *Dictionarium quinque nobilissimarum Europae linguarum Latinae, Italicae, Germanicae, Dalmatiae et Ungaricae* (Dictionary of the five most excellent languages of Europe: Latin, Italian, German, 'Dalmatian' and Hungarian language, Venice, 1595) and the techn(olog)ical manual *Machinae novae* (New machines).

This article will discuss the manner in which Vrančić entered the world of science and became one of the most distinguished techn(olog)ical writers of his time, focusing on *Machinae novae*. Vrančić's extraordinary techn(olog)ical ideas surpassed the possibilities that were at his disposal and many of them have been animated hundreds of years after the publication of this work. The article will show the specificity of Vrančić's work, emphasise the value and peculiarity of his designs and explain his work within the context of the development of Renaissance science. The techn(olog)ical problems which designers of the 16th century dealt with were in a close connection with physics, but it was not yet possible to apply the acquired knowledge and results from physics to the resolution of techn(olog)ical problems of that period. Namely, new discoveries in physics were made, the heliocentric system revived, and the Archimedean and Platonic tradition of physics re-introduced. However, symbolic algebra, which appeared at the end of the 16th century had not been completely constructed yet. Its affirmation, together with the development of mathematical methods, was necessary for all conditions to be fulfilled for the appearance of new areas of physics and of mathematics.[1]

Figure 1:
Machinae Novae, frontspiece

Faust Vrančić (Italian: Fausto Veranzio, Latin: Faustus Verantius, Hungarian: Verancsics Faustus) occupies a special place in the succession of Renaissance thinkers from Croatian soil who contributed outstandingly to the development of Western science. Vrančić worked as an inventor, designer, techn(olog)ical writer, linguist, philosopher, theologian and writer of literary and historical works. He contributed significantly in various fields. He wrote several works amongst which two stand out: his

[1] Dadić (1992): 79-83, 88-92.

penta-lingual lexicon *Dictionarium,*[2] the first dictionary which included the 'Dalmatian' (Croatian) language in the company of the 'five most excellent European languages', and his techn(olog)ical work *Machinae novae* published in Venice ca. 1615/16, which, because of its significance, has undergone several new editions in recent times.[3]

Vrančić contributed to various areas and aspects of human life. Although he did not write mathematical works, Vrančić was interested in mathematics. He studied Euclid's *Elements* (4th century BC), one of the most influential works of antiquity. Through this work, Euclid of Alexandria, who is regarded as the originator of the axiomatic system, had a decisive influence on mathematics in the following twenty centuries. At the end of the Renaissance, the *Elements* became a basis for the further development of mathematics. Euclid's work in its complete form was unknown to Western mathematicians during the greater part of the Middle Ages. With Boethius (480-524/525), the most distinguished mathematician of the Late antiquity, as their model, medieval mathematicians only used individual theorems, without using evidence and the strict axiomatic deductive system, which represents the essence of Euclid's work.[4] The first translations of Euclid's complete work from Arabic into Latin occurred in the 12th century.[5] During the Renaissance,

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[2] Digitalised version of *Dictionarium* is available on the website of National and University Library in Zagreb *http:db.nsk.hr/HeritageDetails.aspx?id=879* (last access 25/1/2017).

[3] German edition (Heinz Moos Verlag: Munich, 1965), Italian (ed. Umberto Forti, Ferro: Milano, 1968), German second edition (Harenberger Kommunikation: Dortmund, 1982), Hungarian (Magveto Könyvkiadó: Budapest, 1985) and Croatian (Novi Liber: Zagreb and Gradska knjižnica Juraj Šižgorić: Šibenik, 1993) – see bibliography. In recent times there have appeared two digital editions, one in Zagreb (see n.2 above) and another on the Internet site of New York Public Library (2012).

[4] For more on the significance of Euclid's *Elements* for the development of Western European mathematics see Dadić (1992): 38-45.

[5] Numerous originals of significant works of ancient Greek science were lost over time, but these works were preserved in Arabic translations. The lost works were carried over with the Arabic penetration of European soil and the systematic translation of these works began in the 12th century in the translating centres of southern Europe. The first translation of Euclid's *Elements* from Arabic to Latin was thus executed by Adelard from Bath. The *Elements* influenced the development of

the first Latin editions of the *Elements* were printed and the work became more accessible in scientific and mathematical circles. It is interesting to note that the Franciscan monastery in Šibenik, which possesses a collection of incunabula, preserves a copy of an incunabulum of Euclid's *Elements* published 1482 in Venice, used by Vrančić himself. This copy contains his handwritten annotation and short supplement, probably taken in part from a later edition of Euclid's *Elements*. The incunabulum from the Franciscan monastery in Šibenik is precious testimony of Faust's interests and knowledge of mathematics since he had been directed toward the humanistic sciences in his formal education in accordance with the wishes of his paternal uncle Antun Vrančić who took care of his schooling.

The patrician family of Vrančić and the education of Faust Vrančić

Faust Vrančić was born on 1st of January 1551 in Šibenik, part of the Venetian Republic at the times, as the son of Mihovil Vrančić and Katarina (née Dobrojević), into a respectable noble family of Šibenik that was connected, through familial ties, with prominent local magnates. The family is considered to have belonged to the Bosnian nobility and have settled in Šibenik in the 14th century as refugees from the Ottoman incursions. The family is first mentioned in 1360 in the documents of the city of Šibenik, in which one finds the name Nikola Vrančić registered.[6] Over time the Vrančić family became kin with several prominent families, amongst which the Divnići, Statilići and Berislavići stood out.[7] For example, Frane Vrančić, the great-grandson of Nikola Vrančić married Margareta Statilić, the sister of the Bishop of Šibenik and Transylvania

Western mathematics almost two thousand years after its inception. A significant role in the revision of the first translation of the *Elements* from Arabic to Latin was played by the first great scientist and translator Herman Dalmatin, who was also of Dalmatian origins. For more on Herman's work on revising the translation of Euclid's *Elements* and his work on mathematical problems and the application of mathematics, see Dadić (1996): 170-85 and in the synthesis on the comparative development of science in three civilizations (Western, Byzantine and Islamic) and their mutual interactions, Dadić (2013): 115-28.

[6] The document is unpublished – see Muljević (1998): 9, 11; Pavičić (2015): 4.

[7] Kukuljević Sakcinski (1991): 42-43; Pavičić (2015): 4-13.

Ivan Statilić (1472-1528).[8] Furthermore, Margareta's aunt, Mandaljena Statilić, was the mother of the Croatian *ban* (viceroy), diplomat, secretary of the Croatian-Hungarian King and the Bishop of Veszprém, Petar Berislavić. Part of the tradition in the Vrančić family was to help in the education of gifted members. A great social importance was attached to the education of the youth, so that Bishop Ivan Statilić and ban Petar Berislavić made provision for the schooling of Faust's father Mihovil and his brother Antun, two sons out of the total of the ten children of Faust's grandfather, Frane Vrančić. Continuing the family tradition of mutual aid, Antun Vrančić provided for the schooling of several protégés, including Faust Vrančić the son of his brother Mihovil. The preserved correspondence between Mihovil and Antun Vrančić shows that the brothers were very attached to one another both privately and professionally throughout their whole lives and raised Faust almost as a common son.[9]

Vrančić began his initial humanistic education in Pressburg (Bratislava), where he arrived from Šibenik at the age of 10 at the invitation of his uncle Antun Vrančić, the ecclesiastical dignitary, esteemed diplomat, statesman, Bishop of Esztergom and Primate of the Kingdom of Hungary.[10] Antun Vrančić enjoyed such a reputation in the Vatican that, before the very end of his life, Pope Gregory XIII planned to appoint him a cardinal recognising his considerable merit for the Christian world in the times when there was fierce fighting against the Ottomans. According to family tradition,[11] Antun Vrančić made provisions for Faust's schooling. After Hungary, Faust went at the age of eighteen to study law and philosophy in Padua. He also showed interest in areas of the natural sciences, and after the end of his studies, supplemented his knowledge from various sources. Faust was interested in techn(olog)ical knowledge and designs and was acquainted with the natural sciences of his time. On 1st of January 1575, he was admitted to membership of the

[8] Vladimir Muljević (1998): 11-13.
[9] Novaković (1995): 5-16.
[10] Varga (1985): 366-67.
[11] Grmek (1981): 613; Novaković (1995): 9, 11, 26-85.

Illyrian (Croatian) confraternity of St. Jerome in Rome.[12] He later maintained links with this confraternity and his fellow-countrymen in Rome.[13]

After this he returned to Hungary. Vrančić's biographers write that there he studied the works of the renowned English philosopher Roger Bacon (1214-1294), the promoter of the inductive method in science and a great visionary of techn(olog)ical development.[14] The literature on Vrančić also mentions that Faust was interested in the works and experiments of the famous Galileo Galilei (1564-1642), who was at one time a professor of mathematics at the University of Padua. However, I have not so far found solid confirmation for these two claims in the documents and existing sources. Somewhat younger than Vrančić, Galilei promoted the development of mathematical methods and their application in the natural sciences, and the systematic use of experiments as a designed and methodically conscious process, with which are posed questions and achieved true knowledge about nature and phenomena in the world. Galilei wrote and affirmed the idea that the book of nature was written in the language of numbers, while Vrančić had only partly been on the trail of these thoughts and considerably more rooted in the earlier scientific heritage. Leaning towards philosophy and natural philosophy, Vrančić, though schooled in the Aristotelian tradition, showed certain aberrations and was acquainted with some new knowledge from physics, which can be noted from an analysis of individual projects from *Machinae novae*.[15]

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[12] Burić (1966): 13-14.
[13] Stošić (1936): 12.
[14] Muljević (1998): 18.
[15] In his more mature period, Vrančić wrote philosophical works in which is showed a departure from the Aristotelian tradition which he adopted through his schooling in Padua. Under the pseudonym Justus Verax Sicenus he printed two philosophical works, *Logica suis ipsius instrumentis formata* (Venice, 1608) and *Ethica christiana* (Rome, 1610). In Venice he published in 1616, under his own name, a partly supplemented and re-written edition of these two works in a common volume under the title: *Logica nova suis ipsius instrumentis formata et recognita. Ethica christiana.* That Vrančić did not follow Aristotle's teaching (according to which he was schooled) to the letter in his later period is attested to by the contents of his logic. He emphasised this himself in the preface to this book. According to the earlier tradition,

His work originated precisely at the end of the period when old conceptions were still being defended, while a new approach based on the application of mathematical methods was progressively affirmed.

From the period of the late Renaissance, physics was no longer based on the qualitative considerations that formed the basis of Aristotle's physics (natural philosophy), but, under the influence of Platonism, supported the mathematical interpretations of natural phenomena. Such a mathematical interpretation of natural phenomena included quantitative considerations of natural scientific problems, which progressively acquired greater importance from the second half of the 16th century onwards. Aristotle's qualities were replaced by Archimedes' quantities, with the awareness that a new physics and mathematics could only be established upon the firm foundations of mathematical philosophy inspired by Archimedes and Plato, which then resulted in their application in the techn(olog)ical sciences. These were only the beginnings of a new approach to physics, especially to the new mechanics that was shaped by Galilei, synthesizing all former criticisms of Aristotle's peripatetic natural philosophy.[16] All these novelties that appeared in science began gradually during Vrančić's life, but their final methodological and conceptual forging was completed immediately after him, so that they are not reflected in his work to a greater degree. Vrančić's designs were described phenomenologically, as was the case with other designers who worked in that time, and in that sense Vrančić as a designer completely followed the

philosophers generally supported the idea that the disposition of logic was found in the fact that it provided instruments for the comprehension of unknown knowledge. On the other hand, Vrančić supported the idea that logic only teaches us the ways knowledge (which is already known) is explained and systematized and does not represent the manner in which we can study the unknown. In his *Ethics*, Vrančić reflected on human's agency on the path to the realization of the final purpose. His *Ethics* was written in the tradition of scholastic philosophy and rested on the sources of the Holy Scripture, Aristotle and St. Augustine. For more on Vrančić's philosophical works, see Jurić (1978): 289-94, Kovač (1988): 17-33; Čvrljak (1996).

[16] The conceptual changes in the natural sciences and mathematics and their application, which appeared during the transition from the Renaissance to modernity, are described in Dadić (1992): 93-97.

technical methodology of his time.

The character of mathematics and the natural sciences during the transition from the 16th to the 17th century

Since mathematics has a high degree of application in the realization of different techn(olog)ical projects and designs, it is worth determining in more detail the character of mathematics in Vrančić's time, and examining the level of mathematical knowledge that he possessed. Faust Vrančić did not write a single work in the field of mathematics, but as previously mentioned, he did study of Euclid's work which originated within the framework of Classical antiquity. Ancient Greek science was particularly researched in the period of the Renaissance and, alongside new methods, represented a specific model and basis upon which an attempt was made to construct a new science. Numerous mathematicians endeavoured to reconstruct and restore the lost works of antiquity. For example, the great Ragusan mathematician Marin Getaldić (Marino Getaldi) (1568-1626) competed with his friends François Viète (1540-1603) and Alexander Anderson (1582-1620) in the restoration of the lost works of Apollonius of Perga (3rd century BC), concerned with conics. Although Faust possessed mathematical knowledge, mathematics was not the focus of Vrančić's interests. He was more interested in practical aspects, technology and other areas to which he could contribute through his works to the quality of everyday life with the aim of making human life easier, better and more worthy. Vrančić did not occupy himself with science simply for the sake of science but through his contribution endeavoured that man and his world develop consistently with the ideals of Christian humanism which he wholeheartedly advocated.

Great changes occurred in mathematics before the end of Vrančić's life. During the Renaissance mathematics was considered the ideal of evidential science. Although strong impulses of change already began in the 12th century when the first translations of original Arabic, and lost works of antiquity were translated from Arabic to Latin, but it was necessary for several centuries to pass for conceptual changes to appear. From the 12th to the 16th centuries knowledge was generally adopted from these two traditions. New knowledge was progressively accumulated and the Western scientific tradition was advanced. Mathematics was supplemented and enriched with new theorems, solutions and problems, but until the end of the 16th century it maintained its concrete character. Until then the abstraction of algebraic operations and separation from their objects had still not occurred. It was considered that operations and the object to which they were applied produced an indivisible whole. Precisely because of that reason it was not possible to arrive at the concept of the formula before this period. The thinking of mathematicians of this period was done within the framework of individual problems and examples, so that they crossed from one concrete problem to another without any greater universality and generalization. Fundamental changes appeared at the turn of the 17th century when Viète introduced a new algebra, in other words the algebraic analysis and symbolic algebra that calculates with general numbers.[17] Marin Getaldić also contributed to the affirmation and development of symbolic algebra, which enabled the reinterpretation of former mathematical results and paved the way for the foundation of analytical geometry and other new areas of mathematics.[18] In general, great changes occurred during the 16th century which opened the door to modern science. Along with the restored heliocentric system, new Neoplatonic natural philosophies were formed which influenced the construction of a new approach to physics. The new physics, together with the development of mathematics and the new symbolic algebra, provided the conditions for the further appearance of new theories and areas in physics and natural philosophical systems.

Impulses and patterns for the making of techn(olog)ical projects

Although there are now written traces in the preserved documents, it is assumed that Vrančić already received the first impulses for the formation of techn(olog)ical projects and solutions at a very early age when, in 1579

[17] Dadić (1992): 88-92.

[18] The mathematical work and contribution of Marin Getaldić to the transformation of modern science is elaborated on in more detail in Borić (2012a); (2012b).

at the age of 28, he performed the duty of the administrator for the Bishop's estate of Veszprém. Two years later he became the secretary of the Holy Roman emperor Rudolf II (1552-1612) and moved to the imperial court in Prague, where he performed various diplomatic and state affairs in the service of the Emperor for years. The new milieu provided Vrančić with the opportunity to deepen his techn(olog)ical knowledge. A cultural circle of outstanding European scientists and engineers of the time was assembled at the court of Rudolf II.[19] It has so far not been confirmed as to what sort of scientific contacts were maintained by Vrančić, but he could have had direct models in the numerous humanists and scientists who were also in service at the court in that time. Numerous respected representatives of Western culture and science were engaged at the court of Rudolf II, who presented himself as an educated ruler and patron of science and the arts. In this network belonged scholars such as the Danish astronomer Tycho Brahe (1546-1601), then his successor at court, the author of the law of celestial mechanics Johannes Kepler (1571-1630), the engineer and builder Adrian de Vries (1556-1626), the great designer of various mechanisms and machines Jacopo de Strada (1507-1588), the philosopher and alchemist John Dee (1527-1608) and many others.[20] The Prague scientific circle probably influenced Faust's development and shaping into a techn(olog)ical writer. In 1594 he left the service of the Court secretary. From then until 1598 he lived in Dalmatia and Italy, mainly in Venice, where he published his petalingual dictionary in 1595. In 1598 Rudolf II granted him the title of bishop of Csanád, which was an honorary office since the bishopric was occupied by the Turks. Vrančić interrupted his literary and scientific work in order to accept an important political assignment, as imperial counselor for Hungarian and Transylvanian affairs at the Court.[21]

Finally leaving Prague and the imperial service in 1605, Vrančić moved to Rome where he received decisive influences for his work. In

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[19] Muljević (1998): 18-20.
[20] Muljević (1998): 19-21.
[21] Grmek (1981): 613.

1608 he entered the order of St Paul, the so-called Barnabites, in Rome,[22] where he met Giovanni Ambrogio Mazenta (1565-1635), who arranged of the collection of techn(olog)ical drawings by Leonardo da Vinci (1452-1519). Besides this, Vrančić, as so many other engineers, designers and scientists in the Renaissance, was inspired by the works of the authors of classical antiquity. A figure of importance in the Renaissance was Archimedes of Syracuse, the ancient mathematician, physicist and designer, and his writtings had a dominant influence on the development of mathematics, natural sciences and technology throughout the entire Renaissance. Other models were the outstanding medieval designers such as Villard de Honnecourt (13th century), whose works were transmitted by younger authors for centuries, while some of ideas are discernible in the initial conceptions of Faust Vrančić, who subsequently enriched them with his own ideas, then transformed them and finally contributed new technically more perfected projects.

Machinae novae in the context of the Western techn(olog)ical tradition

There are no known records of when and how long Vrančić worked on the elaboration of *Machinae novae*. In that time there already existed a certain tradition of techn(olog)ical literature, which Vrančić's work enriched not only with original ideas, but also with modifications of existing projects into more perfected and functional forms.

Western techn(olog)ical literature had been given shape by the end of the Renaissance and the construction of machines had been completely separated from military technology. During the Renaissance, several prominent techn(olog)ical works were written by Leonardo da Vinci, Konrad Kayser, Leon Battista Alberti, Vanocelo Bringuccio, Georg Bauer Agricola, Jacques Besson, Vittorio Zonca, Agostino Ramelli, Jacopo de Strada and others,[23] which was probably a specific expression not only of the total development of science and technology that had materialized on

[22] Boffito (1933): 148-50. Iti s also possible that he entered the order in 1606, cf. Horvat (2001): 12.
[23] Rossi (2000): 31-32.

the threshold of modernity, but also a specific reflection of Renaissance endeavours to advance the quality of human living in all its aspects. Vrančić himself was a part of this Renaissance scholarly network, which is visible in various contributions. Faust did not only contribute to the different areas of technology included in his book, but also reached wider by occupying himself with the patterns of human thinking and interpersonal functioning. Amongst the techn(olog)ical works that originated in Vrančić's time, *Machinae novae* is not the richest or most comprehensive, but can be singled out for its conception and abundance of new ideas, which represented a considerable enrichment of the former techn(olog)ical literature.

If we assume that Vrančić already received his first impulses for the elaboration of techn(olog)ical projects as a young man during the time of his service in Veszprém, and taking into consideration the fact that he printed *Machinae novae* before the very end of his life, it is possible to assume that he gradually prepared himself for this work for nearly forty years. He did not only introduce his own ideas into this book, but also use those respectable ideas that he heard from friends or that he co-opted seeing them already realized in completed projects that he had come across in the different cities of Europe in which he lived or through which he travelled. One can thus partly explain the specific structure and contents of *Machinae novae* into which, besides his own ideas, Vrančić also transmitted, to a certain degree, the ideas of his predecessors.

The contents, structure and main characteristics of the work *Machinae novae*

Machinae novae contains 49 large size plates. After the plates, Vrančić enclosed commentaries in Latin, Italian, Spanish, French and German that described 56 different devices and techn(olog)ical designs. Not all these projects were new, but many were originally Vrančić's and signified a great enrichment of well known technological forms and designs.[24]

[24] The year of publication was not imprinted on the work *Machinae novae*. However, it can be concluded that it was printed at the end of 1615 or the beginning of 1616.

Vrančić examined different techn(olog)ical problems. He studied practical hydrological problems, sought the causes of floods and offered suggestions on how to avoid them. Also, he designed different types of clocks; applied the attributes of elasticity of materials for the accumulation of mechanical energy; designed mills and bridges; developed the idea and role of the flywheel in prime movers; and dealt with the problems of the upstream navigation of rivers and dragging heavy loads whereby he used the parallelogram of forces which was a novelty in science at that time (the law was formulated by Simon Stevin in 1586).

Vrančić was interested in technological processes, the organization and division of labour, and projects for the cutting and threshing of wheat. In the commentaries and interpretations of projects, Vrančić, like his contemporaries, did not use a mathematical apparatus. It is important to mention that, in the time of the Renaissance, mathematical methods were not developed in such a way, and nor were single laws of physics known, that they could generally be applied to the working out of projects in the way that they have been designed from the end of the 18th century and until the present day. It was precisely the development of mathematics and physics after the Renaissance that enabled the accelerated development of technology of the modern period.

Therefore, Vrančić and other authors of similar works and projects in that period could not resolve all the problems that they engaged with. For the resolution of these problems it was necessary to have mathematical, physical and techn(olog)ical knowledge, which was discovered much later. For example, in the case of a many Vrančić's projects (mills, bridges) it was necessary to employ knowledge of the theory of circulation of air and water, while for other groups of projects it was necessary to have static principles and laws, which were only discovered with the gradual development of science in the 18th century. Therefore, it is important to stress that Vrančić, like all other authors of

Since the preserved copies contain some differences it has been presumed that, besides the mentioned work, there existed an edition from 1595 or 1605. Mirko Dražen Grmek has shown that such conclusions are erroneous and that only one edition exists, the one from 1615 or 1616, Grmek (1976): 614.

similar works in this period was only able to phenomenologically interpret and describe his technological designs. In that sense, his work on technological projects was completely incorporated into the general methodology and approach of technological authors of that time.

A list of inventions

It is interesting that Vrančić added a list of his own inventions at the end of *Machinae novae*. He was probably prompted by the desire to make a clear distinction between his own ideas and those that he co-opted as requisite material for his technological manual. Through an analysis of the displayed contents and commentaries it is visible that, in addition to his inventions, Vrančić sometimes showed in the inventions that he had read about or had seen in the cities in which he had resided, or had learned about from friends with whom he shared common interests.[25] Within the chapters to which he added accompanying commentaries for individual projects, Vrančić frequently mentioned the manner in which he had arrived at particular ideas.

Due to the specific structure and contents of *Machinae novae* the question is raised as to why Vrančić included projects belonging to other people at all? In order to answer and explain Vrančić's approach, it is necessary to do this precisely within the framework of *Machinae novae*, conceptually conceived as a manual with its own practical value. Vrančić, who was obviously a typical example of the successful realization of the Renaissance *homo universalis,* was equally favourable to theory and the practical aspects of its application, so that he included some lesser known projects of other inventors in *Machinae novae*. Thereby, Vrančić methodologically succeeded in bringing some projects together with his own ideas into one whole. Such an approach is valuable to intended readers because it provided an insight into the development of specific designs. It

[25] E.g.: the bridge in Vienna; a fire, water and sun clock; a mill in a sea strait; a mill on a bridge made of boats; a mill powered by donkeys; a mill with weights; the separation of flour from bran; a millstone; a bridge with two beams; a wooden bridge; a stone bridge; a bridge made of ropes; a boat that sails upriver on its own; a stone saw; the instrument that pushes water in the air; a horse cart that descends downhill.

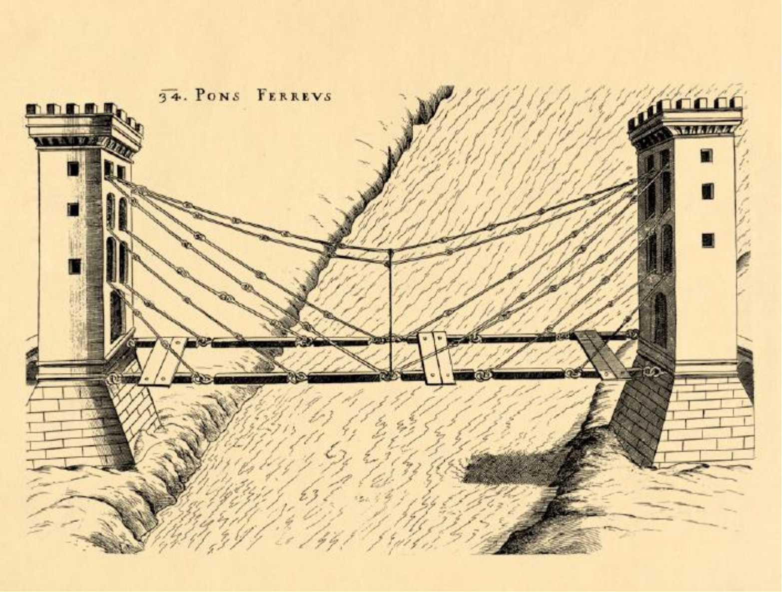
is indisputable that some projects of other authors provided Vrančić with an inspiration for more perfected ideas, but *Machinae novae* itself, along with the abundance of original ideas that it brings, has a value precisely because it shows the developmental component of significant innovations in a clear manner.

Projects for bridges

With his projects in *Machinae novae*, Vrančić encompassed a very wide scope of various areas of technology. However, some themes are more widely represented than others. The group of projects which deal with bridges is one of those themes. Within the group of projects for bridges that have reinforced beams and arches we have a good example which enables one to follow the rational development of Vrančić's ideas and his reasons for citing the previous projects of others. For example, Vrančić began a group of projects for bridges with the co-opted design of a wooden bridge with two beams (project no. 30). This design prompted Vrančić to replace two beams on a wooden bridge with an arch, which he did in project no. 31. Then Vrančić introduced some other modifications. Familiar with the properties of materials, he changed the material out of which the bridge was built and reproduced a similar design of the bridge but now made out of stone and this bridge was represented in project no. 32. Further developing and perfecting the idea of applying different materials, Vrančić finally proposed, in project no. 33, the remarkable and daring idea of building such a bridge from bronze, which is frequently cited as one of his most important and most valuable proposals.[26] Although remarkably important, project no. 33, as with some other of his projects, was not feasible in that time. The first metallic bridge with such an arch was constructed in England in 1773, but, according to modern architectural principles, it was made on the basis of previously executed static calculations.[27]

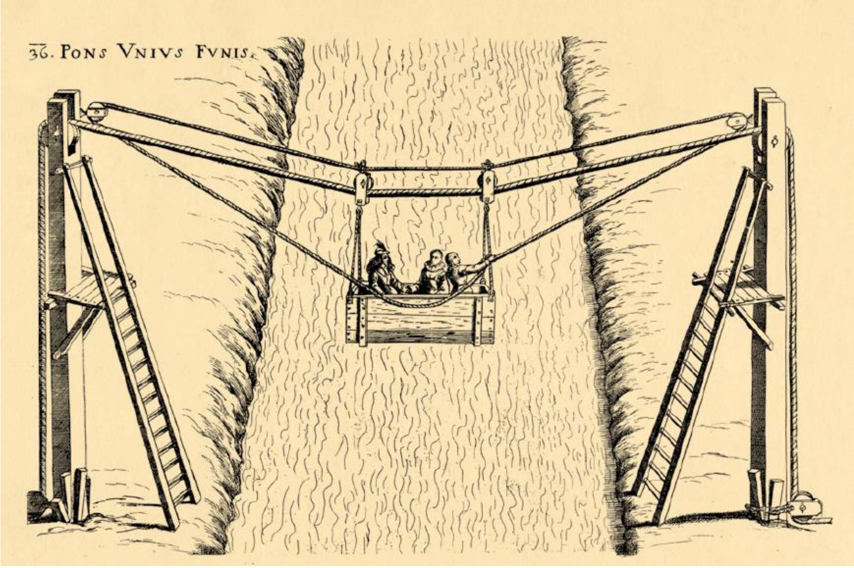
[26] Čalogarić (1944): 51-54.
[27] Wissner (1965): Commentary alongside project no. 33.

Figure 2:
Machinae Novae, project 34: Iron bridge



It is worth stressing that Vrančić was the first to design the idea of a bridge suspended by chains in the project no. 34 for an iron bridge, while the design for a bridge with a rope (project no. 36) is considered the forerunner of the present day funicular railway. Vrančić's idea of a bridge suspended by chains is today widely applied around the world, which is insufficiently recognized and stressed. The first such contemporary bridge was constructed in 1955 across Strömsund in Sweden; with technological progress in building, Faust's chains have been replaced with steel cordages. An example of such a construction is the Anzac Bridge in Australia, or the Dr Franjo Tuđman Bridge in Rijeka Dubrovačka, which has been made in accordance with this principle. A bridge suspended by chains was Faust Vrančić's invention, and which is, after four centuries, one of the most significant in the construction of modern bridges, particularly applicable in the case of large spans.

Figure 3:
Machinae Novae, project 36: A bridge with a rope



Projects for mills

The group of projects which include Vrančić's designs for different types of mills is thematically the largest in *Machinae novae*. In total Vrančić described 18 types of mills, but it is important to note that not all the exhibited projects for mills in this work are Vrančić's original inventions. Vrančić structured this section by first describing the mills of other designers from whom he commenced his technological combinations. The projects nos. 7 and 8 are ideas which we find amongst respectable designers and engineers of the Renaissance: Agostino Ramelli (1588); Walter Ryff (1547); and J. Besson (1578).[28] One of the designs that Vrančić co-opted which is of interest is the project for a mill in a quadrangular tower with a vertical axis that probably originates from the Far East.[29] Then Vrančić continued to exhibit projects which reflected his own ideas. He described a mill with triangular arms (project no. 9) and

[28] Wissner (1965): the commentary alongside projects no. 7 and 8.
[29] Wissner (1965): the commentary alongside project no. 12.

with a vertical axis, which was a complete novelty in the technological literature, while in practice it only appeared in the 18th century. Inclined toward the improvement and perfection of existing ideas, Vrančić saw the advantage of mills with a vertical axis, since this eliminated the necessity of directing the blade wheels with a horizontal axis in the variable direction of the wind. What can generally be said for the group of projects for mills is that Vrančić, regardless of whether he used the projects of his predecessors or whether designed them himself, always endeavoured to point out the most effective and simplest sources of driving energy. This is reflected in all the exhibited projects for mills regardless of whether they were designed to run on wind, water mass, sea current, and manual or animal power. There is one more valuable component of Vrančić's projects, which is important to stress. Although Vrančić did not know the laws of atmospheric and ocean circulation, and could not, like his contemporaries, design the most favourable forms of machine parts such as the blades of mills or windmill arms upon the basis of calculations, he provided very functional solutions and forms.

In addition, amongst the numerous projects for mills represented in *Machinae novae*, it is worth emphasising the construction of a mill that used the tides (project no. 17). Vrančić himself mentioned that he partly co-opted the idea. The idea can be dated to 1438 and the author is stated to be Mariano di Jacopo, the Renaissance engineer who was nick-named the Archimedes of Siena.[30] Vrančić moulded this idea and first published it, which significantly contributed to the affirmation of this project in technology. The idea was brought to life in theory and practice and is still applied, along with modifications, to the present day. In the project for mills that used the tides, Vrančić presented the idea that a mill be placed in a canal which connected a closed artificial lake to the sea. When the sea was raised during the high tide the lake would be filled, while it would be emptied during the low tide and this would move the mill blades. The value of this project has been confirmed by its long-lived application, because it is precisely this foundational idea that is the same as the conception upon

[30] Wissner, A. (1965): the commentary alongside project no. 17.

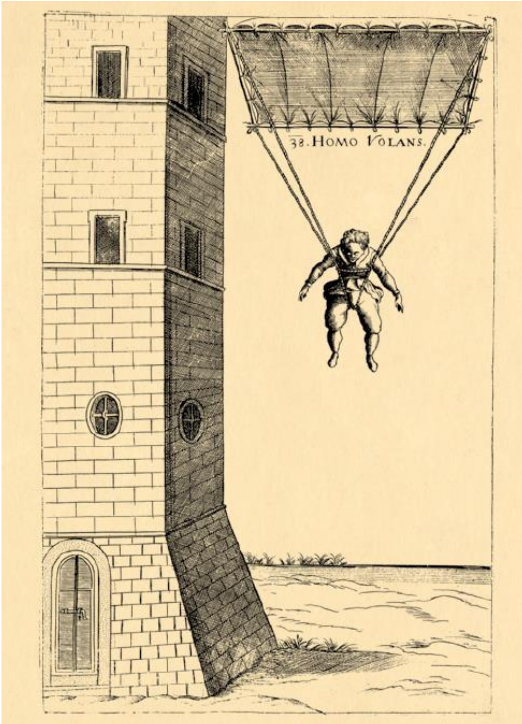
which modern power stations on the Atlantic coast are based. In accordance to the same principles these power stations use great differences in the sea level that arise due to the activity of the tides.

The project for a parachute – *Homo volans*

The project for a parachute exhibited under the number 38 is one of Vrančić's most important and well-known projects. Vrančić was not the first designer who occupied himself with the idea of a parachute. Leonardo da Vinci had already sketched a parachute in his collection of drawings *Codice atlantico*.[31] We cannot confirm whether Vrančić was acquainted with Leonardo's idea of a parachute because he did not state this anywhere in *Machinae novae*. Although Vrančić always clearly indicated the co-option of ideas in his commentaries, there are no such annotations connected to the parachute. It is significant that, in the list of original projects entitled *Our Devices or Machines*, which is found at the end of *Machinae novae,* Vrančić cited the project for a parachute as his own, but he did not call it a parachute, rather he described it in the following words: [To] *descend (jump) from a great height and not be hurt*.

[31] Leonardo was not the first Renaissance designer who concerned himself with the idea of a parachute. Ten years before Leonardo, a sketch was made by the Italian builder, military engineer, inventor and celebrated artist Francesco di Giorgio Martini. But the history of the parachute can even be traced to a considerably older period. The first attempts were made in China, in the 3rd century BC. The British Library holds two drawings of the parachute by an unknown author, which were apparently made by Martini's idea (Ms. Add. 34113, f.200v. i Ms. Add. 34113, f. 189v); Torriti (1998): 42, 43. They are different from each other in the idea and shape of the parachute – one of them is reminiscent of Leonardo's parachute in its construction, but the style of drawing is noticeably different.

Figure 4:
Machinae Novae, project 38: *Homo volans* – the flying man



Although we cannot be certain, it is possible that Vrančić was acquainted with the sketch via the Barnabite Giovanni Ambroglio Mazenta, who arranged the list of techn(olog)ical drawings by Leonardo da Vinci.[32] Vrančić was perhaps inspired by Leonardo's idea, although it is unusual and contrary to his practice to have not mentioned the idea he was co-opting. Besides this, it is important to stress that Leonardo's design had a completely different shape, which reminds one of a conical parachute. Vrančić designed an entirely differently shaped parachute and attached a detailed technical description alongside it. Vrančić's design was the first printed project for a parachute in the history of techn(olog)ical literature. In the description of the parachute, Vrančić stressed the importance of the

[32] Grmek (1976): 613.

size of the linen and the weight of the man. Vrančić's parachute is shaped as a four-squared canvas upon a wooden construction; the sides are very taut so that, at the jump, it creates a reverse pressure that slows the fall.

An echo of Vrančić's parachute and his experiments is present amongst a few authors in the scholarly literature of the 17th century. They refer to the *Mathematical Magick or the Wonders that may be performed by Mechanical Geometry* (1648) written by the English bishop and one of the first secretaries of the Royal Socety - John Wilkins (1614-1672).[33] However, this work neither mentions Vrančić, nor describes his rectangular parachute. Wilkins described the attempt of the jump from the tower on St Mark's square in Venice with a winged device that Wilkins ascribed to the English monk Elmerus.[34] Whether Vrančić or someone else at that time experimented with a rectangular parachure is impossible to say.[35] Taking into account the dimensions of the wooden construction in Vrančić's parachute made of four round crossbars which are around five metres long and connected in a rectangle, the parachutist could not jump independently from the top of the tower – as shown in the drawing. In more recent times there were several attempts to reconstruct Vrančić's and Leonardo's parachute. The conclusion of this experiment was that Vrančić's parachute provides much safer protection to the jumper then Leonardo's, even from more substantial heights. Leonardo's parachutist holds onto the wooden construction with his hands, while Vrančić's parachutist is tied by his waist. Vrančić's *Homo volans* from *Machinae novae*, is the first published project for a parachute in the history of science. Although other people in history experimented with the idea of a parachute, the available evidence leads us to the conclusion that Vrančić's construction is the predecessor of the modern parachute, because it

[33] Škoberne (1957):25; Muljević (1998): 61; Dadić (1994): 132; Nikolić (2015): 82.
[34] Wilkins (1648): 204.
[35] From what is known, the first public experiment with a parachute was organised by the French physicist, chemist, and inventor Louis Sebastian Lenormand in 1783. More then 150 years after Vrančić, he jumped from the observatory in Montpellier from a 20m height, using a parachute tied to the basket in which he was sitting. The experiment was organised for the members of the Lyon Academy, Škorberne (1957): 36.

contains all the elements that the modern parachute has, so we can rightly see his parachute as the ‘father’ of the modern parachute.

Conclusion

For his fruitful and multifarious opus, Faust Vrančić became a metaphor for the Reneissance period in Croatian scholarly and public discourse – the ‘Croatian Leonardo da Vinci’. He behaved as a true Christian humanist of his times, who wanted to improve human life, enrich it and make it worthy of living. It is important to observe that even after four centuries, some of his projects and inventions (metal bridge, a bridge hanging on chains, parachute, etc.) in modified versions are still being used. The work *Machinae novae* presents Vrančić in his inventor’s guise in the best possible light, reflecting his visionary spirit, and anticipating the gigantic development of technology in the centuries after his death.

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Sažetak

U djelu *Machinae novae* (Venecija, 1615/1616) Vrančić razmatra različite tehničke probleme: izučava praktične hidrološke probleme, traži uzroke poplava i daje prijedloge kako ih izbjeći, konstruira različite vrste satova, primjenjuje svojstva elastičnosti materijala za akumuliranje mehaničke energije, konstruira mlinove, mostove, razvija ideju i ulogu zamašnjaka kod pogonskih strojeva, bavi se problemima uzvodne plovidbe rijekom i prevlačenjem velikih tereta pri čemu koristi paralelogram sila koji je u to vrijeme bio novost u znanosti (pravilo izvodi Simon Stevin 1586.). Zanimaju ga tehnološki procesi, organizacija i podjela rada, te projekti rezanja, mlaćenja i vršenja žita. Vrančić se u komentarima i tumačenjima projekata ne služi matematičkim aparatom, kao ni njegovi suvremenici. Važno je napomenuti s aspekta razvoja prirodnih i matematičkih znanosti, da u doba renesanse matematičke metode nisu bile na takav način razvijene, niti su bili poznati pojedini fizikalni zakoni da bi se uopće mogli primijeniti u razradi projekata, na način kako se to konstruira od konca 18. stoljeća, pa sve do današnjih dana. Upravo je razvoj matematike i fizike koji se uslijedio nakon renesanse, omogućio ubrzan razvoj tehnike novog doba. Stoga Vrančić, kao ni drugi tadašnji autori sličnih djela i projekata, nije mogao riješiti sve probleme kojima se bavio. Za rješenje tih problema bila su potrebna matematička, fizikalna i tehnička znanja koja su upoznata mnogo kasnije. Tako na primjer u slučaju velikog broja Vrančićevih projekata (mlinovi, mostovi) bilo je potrebno poznavati teoriju strujanja zraka i vode, za druge skupine projekata bila su potrebna statička načela i pojedini zakoni do kojih spoznaja se došlo postupnim razvojem znanosti tek u 18. stoljeću. U skladu s renesansnim znanstvenim prilikama i dotadašnjim razvojem znanosti, Vrančić je, kao i svi drugi autori sličnih djela tog doba, mogao svoje tehničke konstrukcije samo tumačiti i opisivati fenomenološki. U tom smislu njegov je rad na tehničkim projektima u potpunosti bio uklopljen u opću metodologiju i pristup tehničkih autora tog doba.